POWER PLANT ENGINEERING

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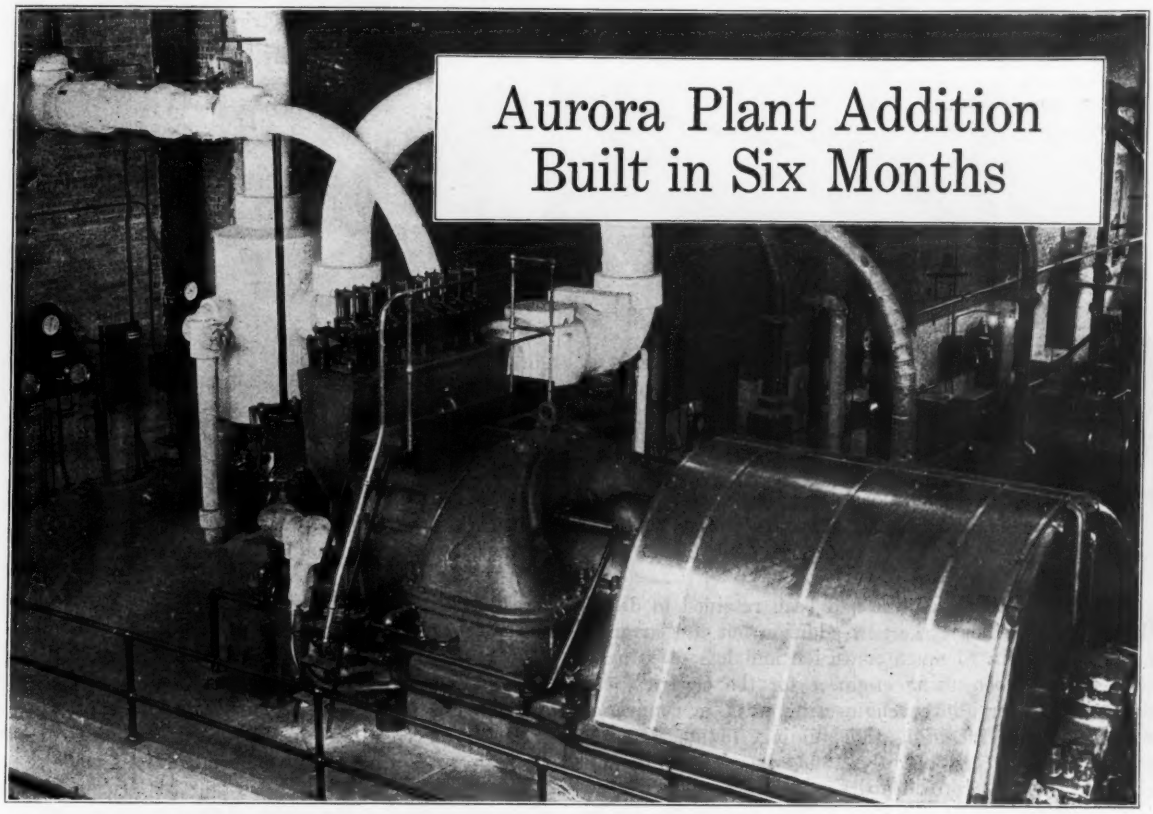


Aurora Plant Addition Built in Six Months

ADDITION TO EXISTING PLANT TO TAKE OVER BLOCK LOAD CONSISTS OF TWO 6000-KW. BLEEDER TYPE TURBO-GENERATORS AND THREE 1000-HP. STIRLING BOILERS

ABOUT TWO years ago the Aurora, Elgin and Ghicago R. R. Co. operating the city traction lines in Aurora and Elgin, Ill., and the interurban lines between Yorkville and Carpentersville and supplying energy for power and light in Elgin purchased their power from the Chicago, Aurora and Elgin Railroad, which also supplied power to the Chicago Suburban Power & Light Co. from the single power plant which it operated.

Due to an increase in load on this system, the Fox River Division was unable to purchase from this source all the power that it needed, consequently it was in the market for power from some other source. The Western United Gas & Electric Co., operating a central station in Aurora, undertook to supply this demand and on May 14, 1923, negotiated a contract to supply the total estimated load of 4217 kw. beginning Jan. 1, 1924, the time when the contract then in force, expired.

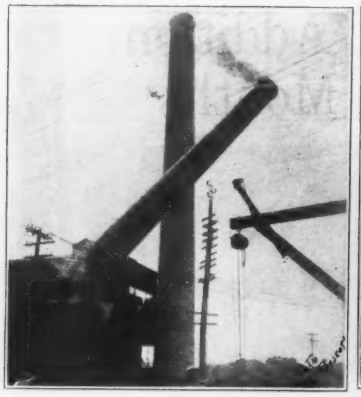
When the present contract was made it became necessary to make arrangements, and to make them quickly, for providing additional generating equipment to take over the load on the specified date. As there was less than 8 mo. in which to complete the installation of the additional units, it was thought that the only possible way to get delivery would be to purchase second-hand equipment for temporary use until the manufacturers could guarantee delivery on new equipment. Accordingly, representatives of the company, W. M. Willet, general manager, and M. F. Pierce, superintendent, set about to locate such second-hand equipment as would serve the purpose. They were successful in locating three or four possible generating units but in the meantime they had taken the matter up with the manufacturers of this type of equipment and found that the General Electric Co. would undertake to deliver two turbo-generator units in time to be put on the line by the first of the year.

At this point, the engineers of the company concluded that it would be a good time to go to high pressure and superheat and also high voltage if they ever intended to take such steps, so it was decided, on comparatively short notice, to purchase new General Electric equipment to operate on 300 lb. pressure and 200 deg. superheat and to generate at a potential of 13,800 v. At this time, the consulting engineer, Warren D. Spengler, Inc., of Cleveland, Ohio, was called in to lay out the electrical system from the generator leads to the point of distribution.

Having thus settled the question of the generating equipment, the company engineers set about to find the necessary boiler, stoker, piping and auxiliary equipment. It was finally decided to install Babcock & Wilcox Co. Stirling boilers with Harrington chain grate stokers.

addition to the main generating equipment located on a reinforced concrete floor above the generator floor of the old plant approximately on the same level with the switchboard gallery of that section, the new plant houses also the exciter units for the new generators, two rotary converter sets for supplying direct current for the local traction system, all condenser auxiliary equipment, main generator and transfer bus structure, in a separate room to the south, and the switchboard gallery for controlling the new equipment and the new load. The new 320-lb. boilers are located in the old boiler room, two on one side and one on the other side of the firing aisle. The four 250-hp. boilers were removed to make room for the new units.

The two new General Electric Co. turbo-generator units are identical in every respect; the generator, is a 60-cycle,



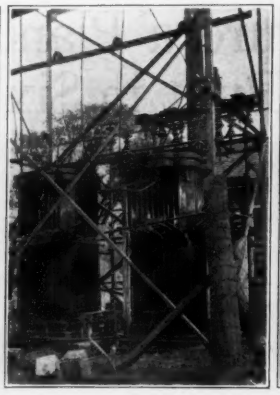


FIG. 1. OLD CHIMNEY FELLED TO MAKE ROOM FOR NEW ONE FIG. 2. HEAVILY OVERLOADED TRANSFORMERS IN THE OLD SECTION HAD TO BE COOLED WITH WATER SPRAY TO KEEP THEM IN SERVICE
FIG. 3. TURBINE FOUNDATION EXTENDS DOWN TO BED ROCK

At first a local architect had been retained to design the building to house the new addition but this arrangement resulted in so much confusion and loss of valuable time that the consulting engineer for the electrical end finally took over all the engineering work in connection with the plant, including the building, foundations and piping. By the first of July, 1923, the plans were sufficiently well along to enable the contractors to start building operations and at this time ground was broken for the new building. From that date until Jan. 1, 1924, an elapsed time of just 6 mo., all the equipment was installed and put in operating condition. This was a gigantic task which was successfully accomplished largely because of the enthusiasm and loyal support of the workers. One generator was put on the line for local service about the 15th of December and both units were available for taking on the new load the first of the year.

Originally, the plant, supplying power at 2300 v., largely for local consumption, consisted of four 250-hp., two 400-hp. and four 500-hp. Stirling boilers supplying dry saturated steam at 160 lb. pressure to five turbo-generators. The total capacity of 9400 kw. is distributed, 1000 in the first, 500 in the second, 1200 in the third, 3200 in the fourth and 3500 kw. in the fifth unit. This last unit supplies exhaust steam extracted from the second stage at a pressure of from 8 to 12 lb. gage for heating the downtown district of Aurora.

The new addition to the old building extends to the south. It is of face brick construction built on a concrete foundation extending down 5 or 6 ft. into bed rock. In

three-phase unit which operates at 3600 r.p.m. and delivers, at the rated load, 6000 kw. at 80 per cent power factor or 7500 kv.a., 314 amp. per phase at a potential of 13,800 v.

The air circulating system for cooling the generator is of the closed type. Cooling is effected by means of a General Electric cooler built in the form of a surface condenser through which a portion of the condensate is made to pass. The unit is composed of some 250 7-ft. tubes. A baffle plate is provided at the center of these tubes in such a way that half of the air to be cooled passes over each side. The unit is located directly below the generator through which a flow of 21,000 cu. ft. per min. is maintained by fan blading built into the generator rotor. With a condensate temperature of 85 deg. F., the cooling effect is sufficient to keep the generator temperature within the maximum allowable rise of 50 deg. C.

The prime mover is a Curtis five-stage condensing turbine taking steam at 300-lb. throttle pressure and from 180 to 200 deg. superheat, depending on the load, and exhausting against about 0.7-in. mercury absolute back pressure. Under these conditions and at rated capacity, the water rate is about 11.8 lb. per kw.-hr. varying somewhat with the amount of steam bled for feed heating.

Owing to the urgent demand for speed in installing this equipment and to the fact that delivery could not be made in time on a 6000-kw. generator, the first unit was installed with a 5000-kw. generator driven by a 6000-kw. turbine. This generator was replaced a few months later with one of the required capacity.

To handle this equipment during the process of instal-

lation, the turbine room is provided with a 50-T. Cleveland crane having a span of 48 ft. across the room from east to west. This crane weighing some 66,000 lb. is equipped with three General Electric motors, the hoist motor having a capacity of 30 hp., the bridge travel, 30 hp., and the trolley motor 10 hp.

Excitation current for both generators is supplied by either one of two independent exciters, one of which is steam and the other, motor driven. The steam unit is a compound wound 600-amp. 125-v., 75-kw. General Electric generator direct connected to a Curtis two-stage 75-kw. non-condensing turbine operating on 300 lb. pressure and 200 deg. superheat and running at 1200 r.p.m. The motor driven unit consists of a compound wound 720-amp. 125-v. 90-kw. generator direct connected to a 135-hp. 1160-r.p.m. induction motor taking at rated load 32 amp. from the 2300-v. bus. This is the generator bus in the old station which can be also tied in through transformers to the 13,800-v. generator bus in the new plant.

by 6 ft. at the entrance and is protected by either one of two Rex traveling screens, each driven by a 3-hp. motor, which serve to keep trash out of the circulating system. The screens travel at the rate of 2 ft. per min. and there is therefore small likelihood of a stoppage of flow due to clogging. From the intake tunnel the water is pumped by a 20-in. centrifugal pump against a total dynamic head of 19 ft. through the condenser. This pump handling 11,650 g.p.m. requires 78 hp. which is supplied by a direct connected 100-hp. G. E. slip ring induction motor operating at 600 r.p.m.

During the winter months the raw circulating water comes to the condenser at temperature of from 32 to 40 deg. and leaves at a temperature of from 40 to 45 deg. During the summer months the average intake temperature will vary from 65 to 60 deg. and the average discharge temperature, from 75 to 85 deg. F.

Condensate is removed from the bottom of the condenser by a 2½-in. centrifugal pump, operating against a

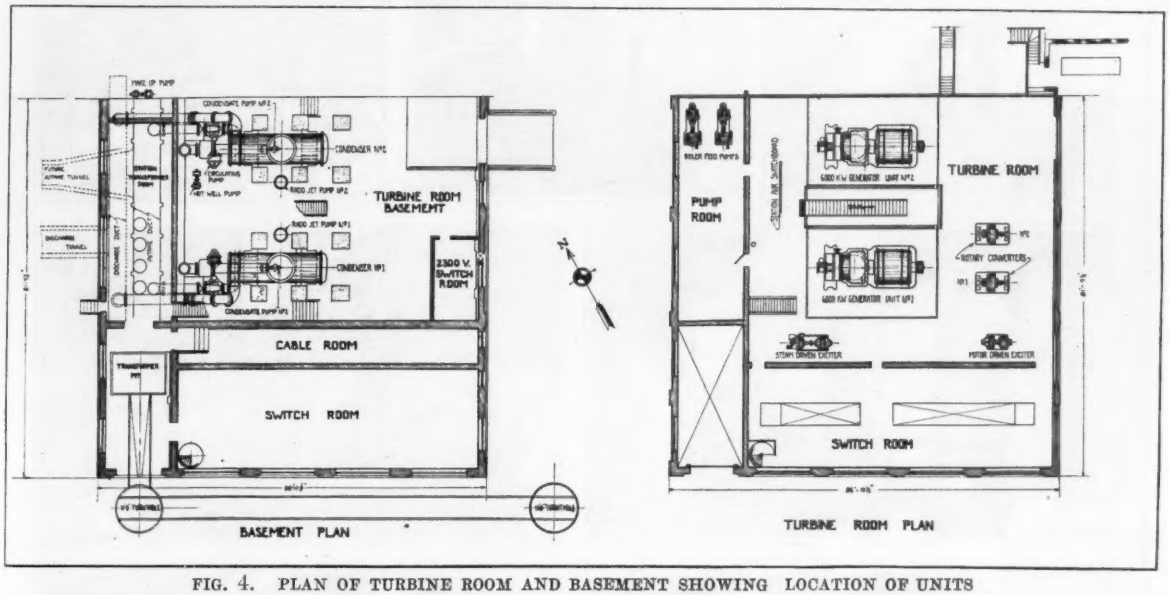


FIG. 4. PLAN OF TURBINE ROOM AND BASEMENT SHOWING LOCATION OF UNITS

Mounted directly below the turbine on a separate concrete foundation is the condensing equipment for each unit. This is a C. H. Wheeler surface condenser having 10,000 sq. ft. of cooling surface, 1.66 sq. ft. per kw. served, at rating. It is connected to the turbine through a circular corrugated expansion joint 66 in. in diameter and a short distance piece, from which is taken an exhaust line for non-condensing operation. The condenser is made up of about 2000 1-in. O. D. No. 18 B. W. G. seamless drawn brass tubes, 18 ft. 3 in. long, held between Muntz metal tube plates and ferrules. Lanes are provided between the tubes for the easy passage of steam and a baffle is placed at one end between the tube sheet and the shell to provide for two passes of the circulating water. At 2-in. absolute back pressure, the unit is capable of condensing 97,200 lb. of steam per hour with a cooling water flow of 11,650 g.p.m. at 70 deg. F. Under these conditions 60 lb. of water is required per pound of steam condensed and the unit condensing capacity is 9.72 lb. of steam per sq. ft. of tube surface per hour.

Cooling water is supplied through an intake tunnel about 200 ft. long from the Fox River. This tunnel is 6

total head of 35 ft. This pump at the rated capacity of the condenser requires 13 hp. which is supplied by a 15-hp. 220-v. squirrel cage induction motor operating at 1800 r.p.m.

Air is removed from the condenser by means of twin Radojet ejectors equipped with inter and after condensers which require 450 lb. of dry steam per hour at 150 lb. gage. Ordinarily one jet is of sufficient capacity to maintain the vacuum at the desired point.

Tests for air tightness of the condenser and connections are made periodically. With the ejectors cut out of operation, the system is considered tight if, over a period of 10 min., the pressure does not rise more than 3 in. of mercury.

Three 1000-Hp. Boilers Are Installed

Steam is generated at 320 lb. pressure by three new Stirling type boilers known as class 13 which have each a capacity of 1001 hp., corresponding to a heating surface of 10,012 sq. ft. Operating at 250 per cent of rating, one boiler is capable of supplying all the steam required by one turbine at rated capacity. Under these conditions of operation there is 1.69 sq. ft. of boiler heating surface per kilo-

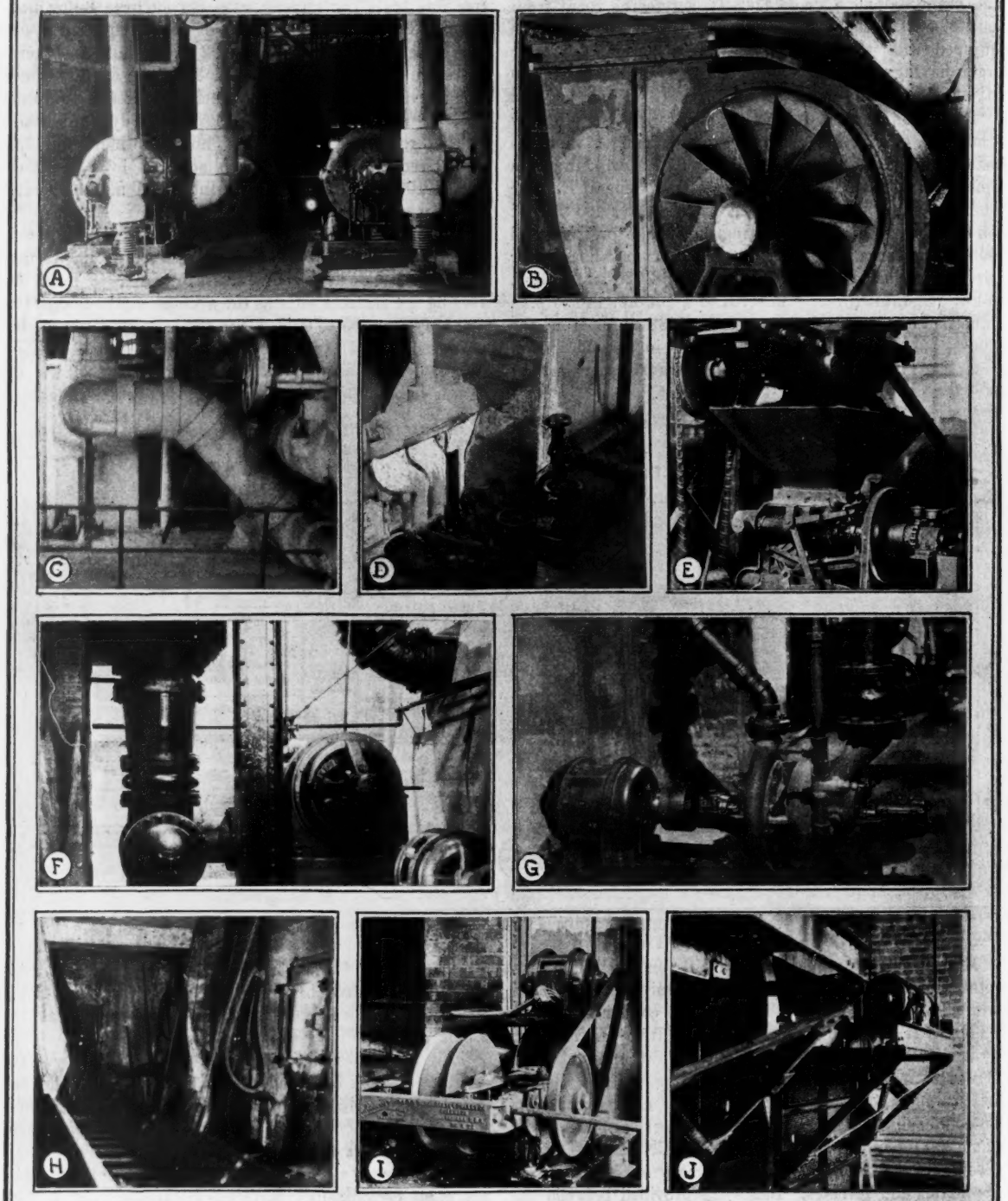


FIG. 5. AUXILIARY EQUIPMENT AT WESTERN UNITED PLANT

A. Duplicate turbine driven boiler feed pumps. B. Forced draft blower for one 1000-hp. boiler has a capacity of 45,000 cu. ft. per min. C. Feed water is heated in a 6000-hp. Cochrane open heater. D. Radojet ejectors maintain a vacuum of 0.7 in. mercury absolute on the condensers. E. Coal to each stoker is weighed in a Richardson automatic scale. F. Circulating pump handles 11,650 g.p.m. through the condenser. G. Condensate pump returns condensate to hot well against a total dynamic head of 35 ft. H. Ash is handled by a Stephens-Adamson bucket conveyor. I. Stokers are driven by a 5-hp. constant speed motor through a Reeves transmission. J. Rex traveling screens are installed at entrance to tunnel to keep trash out of the circulating water.

watt capacity served. At present, however, with only one turbine on the line, most of the time, two boilers are maintained under pressure and are operated at less than this maximum capacity. This boiler is of the new Stirling type, having all three upper drums on the same level. Feed water is introduced into and steam is taken from the rear drum. The unit is 36 tubes wide by 16 deep and contains 576, 3-in. tubes. The upper drums are each 42-in. diameter by 21 ft. 10¼ in. long, made of 1⅜-in. steel. The bottom drum is 48 in. in diameter and made of $1\frac{9}{16}$-in. material. The baffling is of the regular Stirling type, giving three passes of the flue gases through the setting. The combustion chamber is provided with two American suspended arches, the front one being 19 ft. 6 in. wide by 8 ft. deep, and the rear one 19 ft. 6 in. wide by 5 ft. 4 in. deep.

Steam is superheated in a Foster suspended type superheater installed between the first and second passes, which has sufficient surface to insure a superheat of 200 deg. at 200 per cent of boiler rating when the steam supplied by the boiler proper contains not more than 1 per cent of moisture. At this rating, it is guaranteed to deliver steam with not more than 1 per cent of water. The surface is distributed in 42 elements spaced across the width of the setting. The safety valve on the superheater is set to blow at 315 lb. pressure, 5 lb. below that at which those on the boiler proper are set to blow.

Coal is burned on a Harrington chain grate stoker which because of the overlapping grate elements is suitable for the fine screenings used. It is 15 ft. wide by 15 ft. long, having thus 225 sq. ft. of surface, and carries a fuel bed from 6 to 9 in. deep. The stoker is driven by a constant speed induction motor of 5 hp. capacity, driving through a Reeves transmission system, having a continuous speed range, and a system of spur and worm reduction gearing.

Ordinarily either Illinois, Indiana or Kentucky screenings having an average heating value of about 12,000 B.t.u. per lb. is used. Coal is brought in by rail on a trestle and either dumped into a track hopper for immediate delivery to the boiler room or carried out further and dumped for storage in the yard. Coal that is dumped in the hopper is fed by an apron conveyor to a Stephens-Adamson single roll crusher which reduces the coal to a uniformly small size. From the crusher the coal drops into a pivoted bucket elevator and is carried up to a point above the boiler room firing aisle where the buckets are tripped and the coal is dumped on a belt conveyor running the length of the boiler room bunker. This belt is equipped with an automatic traveling tripper which distributes the coal in the suspended type overhead bunker. From the bunker the coal is discharged through Richardson automatic scales and down spouts to each of the stoker hoppers.

Coal is handled in the yard by a Barber-Greene gasoline engine driven bucket loader which delivers to a portable motor driven belt conveyor which in turn delivers the coal to a pivoted bucket conveyor.

The total coal storage normally carried amounts to about 20,000 T. which at rated load on the station is sufficient for about 100 days as the average coal consumption per day amounts to about 200 T.

Ash is deposited over the end of the grate into a storage bin having a capacity, with the coal that is being used at present, for about 6 hr. run of the stoker at 200 per cent rating. These bins are provided with side doors in the boiler room basement from which the ash is shoveled out into a bucket conveyor running the length of the boiler room basement, immediately in front of the ash bins. This conveyor deposits ash at the end of the run into the same pivoted bucket conveyor that handles the coal and is elevated and carried over to an ash storage bin mounted over the railroad tressel. From here the ash is dropped through a bottom gate into standard cars and is thus disposed of.

The total power requirements for the coal and ash handling equipment inside the plant proper, all of which was supplied by the Stephens-Adamson Manufacturing Co. amounts to 65 hp. distributed, 25 hp. for the crusher, 15 for the pivoted bucket elevator, 10 for the overhead belt conveyor, 10 for the ash conveyor and 5 for the apron conveyor.

Air for combustion is supplied by a Buffalo Forge blower located directly under the rear end of the setting. This blower operates at 1160 r.p.m. and is capable of delivering 45,000 cu. ft. per min. under a static pressure of 6 in. of water. The power requirement under these conditions of operation is 45 hp. which is supplied by a direct connected induction motor of 50-hp. capacity. The characteristics of the blower are such that the pressure rises

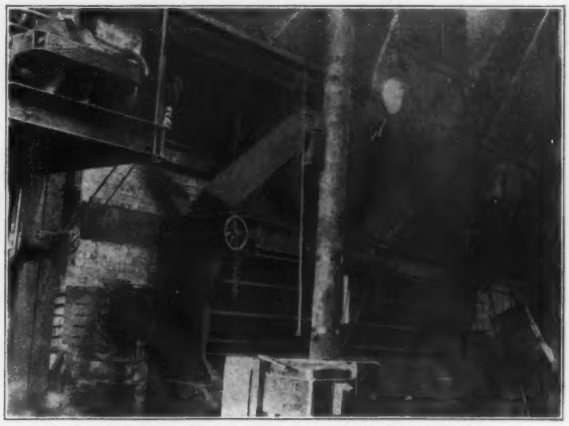


FIG. 6. THREE 1000-HP. STIRLING BOILERS EQUIPPED WITH HARRINGTON STOKERS ARE USED

with decreased capacity which provides protection against overloading the unit. The air is delivered to the stoker through five zones, the flow through which is independently controlled by the adjustment of dampers which may be operated from the boiler front. Ordinarily, the pressure in these zones varies from about 1½ to 4 in., varying, of course, with the rate of firing.

Normally, the flue gas temperature is about 460 deg. at rating, 500 deg. at 150 per cent, 545 deg. at 200 per cent and 590 deg. at 250 per cent. The corresponding overall boiler furnace and grate efficiency is approximately 74 per cent at rating, 76 per cent at 150 per cent, 76 per cent at 200 per cent and 73 per cent at 250 per cent of rating.

Two new chimneys built by the General Concrete Construction Co. of Chicago have been erected to care for both the old and the new boiler installations. The one on the east, 225 ft. high above the grates and 13 ft. diameter at the top takes care of two of the new 1000-hp. units and two 400-hp. units. The stack area amounts to 102 sq. ft., 3.6 sq. ft. per 1000 sq. ft. of boiler heating surface served. The second chimney, that on the west is 200 ft. high above the grates by 13 ft. diameter at the top. This chimney

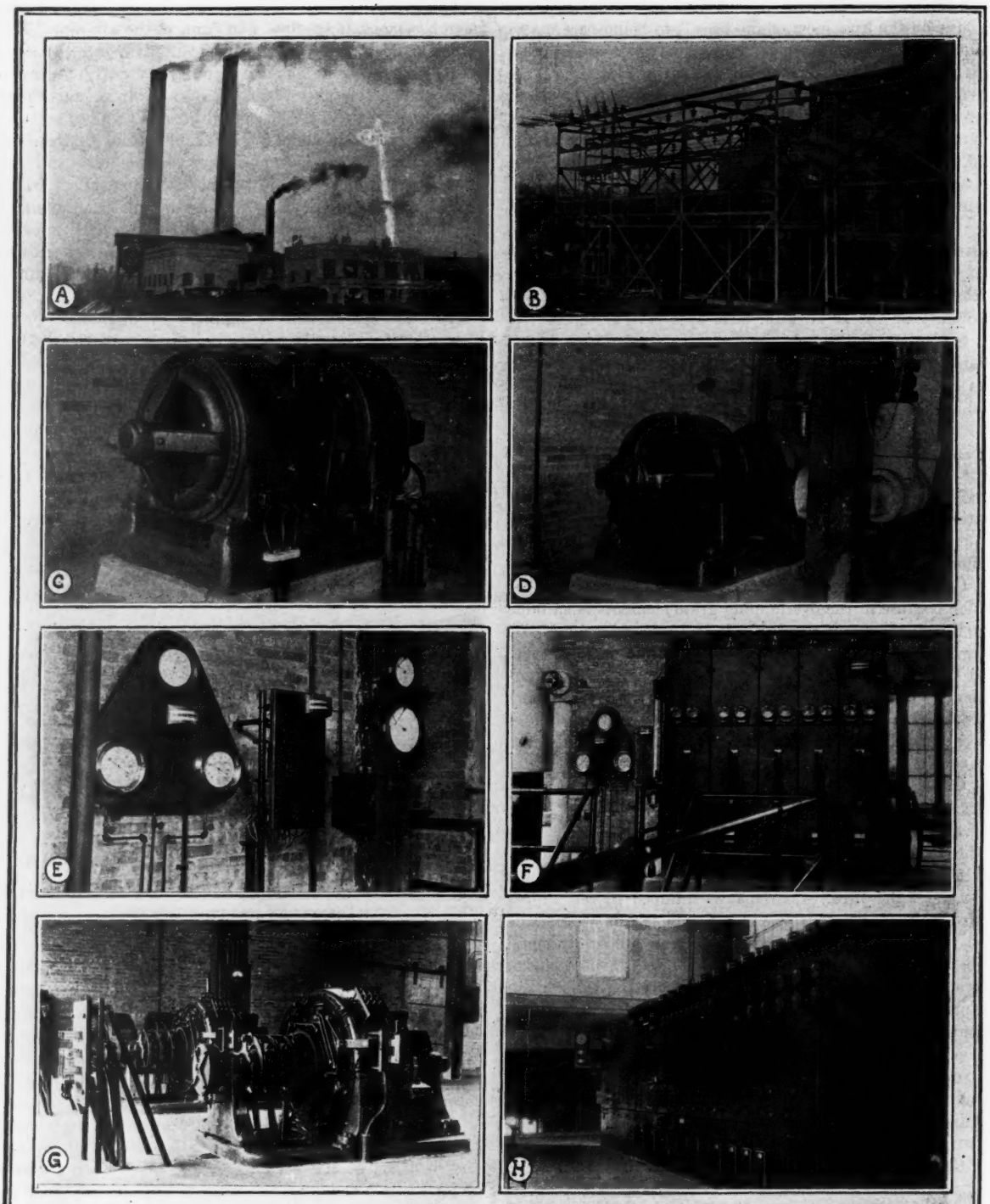


FIG. 7. ELECTRICAL EQUIPMENT IN THE NEW PLANT

A. Total plant capacity is now 21,400 kw. B. Outdoor switching equipment and transformers where the energy is stepped up from the generator potential of 13,800 v. to 33,000 v. for transmission to Elgin. C. Motor driven exciter usually employed. D. Turbine driven exciter is held as a standby. E. Control of the turbine-generator is facilitated by indicating and recording gages and meters located immediately adjacent to the turbine end of each unit. F. Generator control panels are located between the two units. G. Direct current is furnished to the local traction system by two synchronous converters. H. Vertical switch and control boards are located on a balcony over the turbine room. The board controls all generators, bus tie switch, transformers, converters, etc.

takes care of four 500-hp. boilers, and one of the new units. Each chimney is located directly outside of the boiler room to the north, in line with each line of boilers. Flue gases are handled through a breeching which gradually increases in size to 21 by 8 ft. at the point where it enters the chimney. The chimneys are of reinforced concrete construction and are brick lined part of the way up. The outside diameter at the base is 19 ft. and the whole rests upon an 8-ft. thick concrete foundation extending down to bed rock. The shell is 15¼ in. thick at the base and tapers to 5 in. at the top.

Each new boiler is provided with twelve Diamond soot blowers arranged six on each side. Five on each side are for the main heating surfaces and one on each side is for the superheater elements.

Hays draft gages are provided for keeping track of the draft losses through the setting and the draft over the fire. Ordinarily best results are obtained with a draft of from 0.1 to 0.15 in. over the fire. No permanent CO_2 recorders are installed but collecting tanks have been provided in connection with each furnace for taking samples of the flue gas to be tested by a hand Orsat apparatus.

At the present time combustion is controlled by hand operation of the uptake dampers, the dampers in the fire air chambers under the grate and the Reeves drive for the stoker. Eventually, however, an automatic combustion control system will be installed to regulate the coal feed and gas flow from the boiler pressure and the overfire draft.

Although they are not as yet installed, G. E. steam flow meters will be provided on each of the 8-in. high pressure boiler leads and a G. E. feed water meter will be put in the high pressure feed line. Copes feed water regulators are installed to maintain the desired water level in the boilers.

Make-up water is taken from the condenser discharge tunnel and pumped into the hotwell from which it passes to the feed water heater and from there direct to the boiler. This water is taken originally from the Fox River which ordinarily carries scale forming material to the extent of from 15 to 25 gr. per gal. depending on the season of the year and the flow of the river. No attempt is made to eliminate this scale outside of the boiler but is taken care of in the boiler itself by an Elgin blowoff system made by the Reiter Co. of Elgin. The system is in reality a continuous blowdown arrangement consisting primarily of a tank of about 50 or 60 gal. capacity located beside the boiler. This tank is provided with a connection to a point below the lowest water level in the rear upper drum and to the regular blowoff line from the lower drum. Convection currents in the boiler set up a flow which continually bypasses a portion of the water circulated. This bypassed water carries a certain amount of precipitated scale forming material which is deposited out in the tank, due to the low velocity of the circulation at this point, before it has had a chance to adhere to the heating surfaces. This sediment which is continually accumulating is blown off at suitable intervals and the boiler heating surfaces are thus kept comparatively clean.

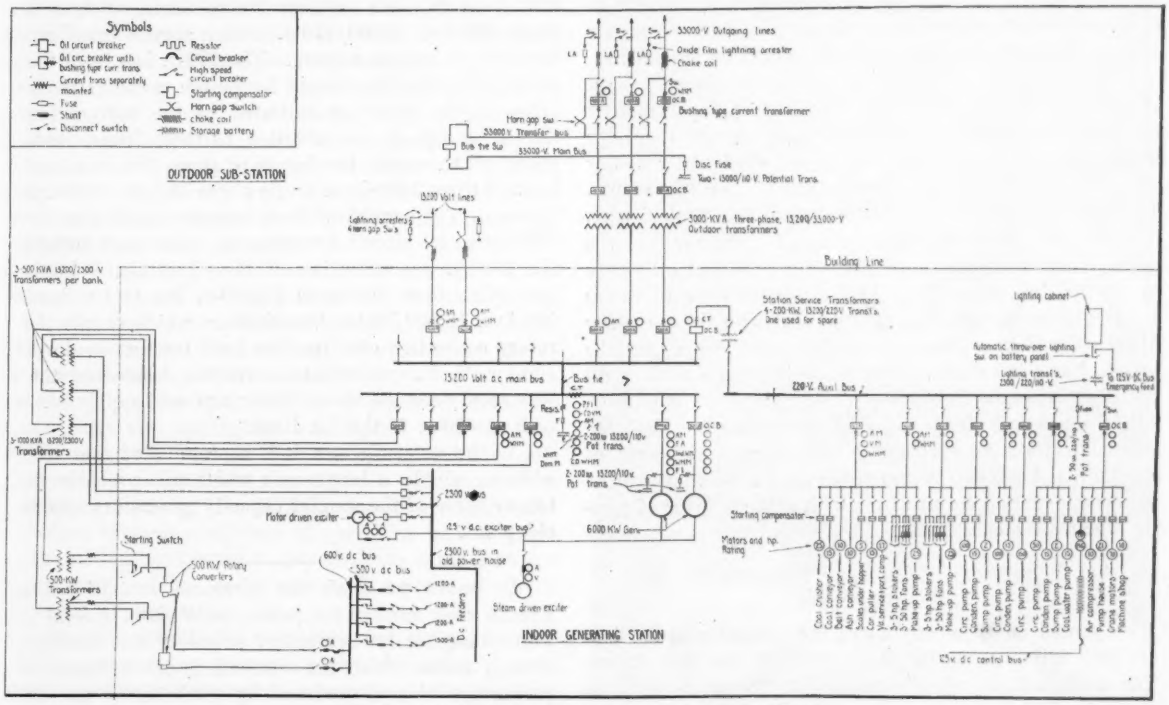


FIG. 8. ELECTRICAL LAYOUT OF THE NEW PLANT

Ordinarily about 80 per cent of the scale forming material is precipitated out by the action of the heat alone, the remaining 20 per cent is taken care of by the addition of a composition consisting essentially of lime and soda ash which is fed into the rear drum from a small tank located directly above. With this system of water treatment, it is found that after four months of continuous operation at around 200 per cent of rating, that the scale on the tubes was about 0.01 in. thick. The cost of this treatment ranges from about 2 to 2½ cents per 1000 gal. of water treated or per 10,000 gal. of water evaporated.

Condensate from the main turbine together with that portion bypassed through the generator air cooler is pumped first to the hotwell and thence by an American

Well Works pump driven by a 15-hp. motor to the open feed water heater; a Cochrane unit having a capacity of 6000 boiler hp. Feed water is pumped to the boilers by either one of two Cameron centrifugal boiler feed pumps located below the heater. These are 4-stage units and have a capacity of 400 g.p.m. each, under a head of 780 ft. They operate at 2400 r.p.m. and are direct connected to a Curtis two-stage turbine of 150-hp. capacity, operating non-condensing on high pressure superheated steam. One of these pumps is of sufficient capacity to handle all of the feed water for the three units; the other is held as a standby unit.

Feed water is heated to a temperature of from 195 to 200 deg. F. by the exhaust from the feed water pump turbine and the exciter turbine, when it is in operation, and by steam bled from the second stage of the main turbine at a pressure of 25 lb. gage. The quantity bled is automatically regulated by a Powers thermostatic regulator in the feed water heater which controls a compressed air operated pressure reducing valve in the extraction line.

Condensate from the high pressure lines is tapped off at suitable points and piped to a receiver in the condenser room. This receiver is equipped with an S-C regulator which opens the discharge line to the feed water heater when the tank is full and closes it when it becomes empty. The action is similar to a thermostatically controlled trap.

All piping work was done by Geo. B. Weatherwax; the piping itself was supplied by the Crane Co. and all valves by the Lunkenheimer Co. At the present time all valves are manually operated but are provided with the necessary fittings for Payne Dean automatic control which will be installed at a later date. Van Stone joints are used on all the high pressure lines; no welded joints are employed. All high pressure steam and feed water lines are insulated with Johns-Manville covering consisting of a layer of sponge felted asbestos on top of which is a 2-in. layer of 85 per cent magnesia covered over with a ½-in. layer of plastic asbestos cement.

All Electrical Equipment Supplied By One Manufacturer

Mounted on a balcony above the generator room floor are two switchboards for the control of the new station. The main a.c. board is composed of 23 panels and the auxiliary d.c. board, 4 panels. On the left of the main board is a swinging bracket carrying a synchronizing indicator and lamps. The board itself mounts controls for the main generator, induction motor and exciter, bus tie switches, transformers and synchronous converters, the main 13,800/33,000-v. transformers, the 13,800/2300-v. transformers, high tension bus ties, outgoing lines, and the battery charging equipment. It also carries voltage regulators, totalizing recording meters and indicating voltmeters and ammeters.

The d.c. board carries controls and both recording and indicating meters for the 600-v. d.c. traction system supply.

All equipment is remotely controlled by a 125-v. d.c. circuit supplied by a 60-cell storage battery. This battery is kept charged by a small 4¾-kw., 175-v. generator driven by a direct connected 10-hp. induction motor. All electrical equipment from the generator to the high lines was furnished by the General Electric Co.

Current is generated by the two new generators at a potential of 13,800 v. and delivered through 500-amp. oil circuit breakers to the main generator bus which is connected by a bus tie with a transfer bus from which lines are taken off to each of three 3000-kw., 3-phase 13,800/33,000-v. transformers. The secondary of these transformers feed through 400-amp. oil circuit breakers and disconnect switches to the main 33,000-v. bus. From this bus leads are taken through disconnects and 400-amp. oil circuit breakers and choke coil to the 33,000-v. outgoing lines to a substation at Elgin. These lines are protected with General Electric Co. oxide film lightning arresters. Leads are also taken from the 33,000-v. transfer bus through horn gap switches to the outgoing lines. This transfer bus may, on occasion, be tied in to the main bus through a 400-amp. oil circuit breaker and disconnect switch.

Transmission lines are also taken off from the 13,800-v. bus through 500-amp. oil circuit breakers, choke coils and horn gaps to supply local power needs. These latter are protected with electrolytic lightning arresters. Another lead from this bus supplies the primaries of four single phase 200-kw. 13,800/220-v. station service transformers; the extra is held as a spare. The 220-v. bus from the secondary side supplies current for all the motor driven auxiliaries in the plant as indicated in the wiring diagram shown in Fig. 8. In addition to these items, leads are taken off to supply two banks of three 500-kv.a. and one bank of three 1000-kv.a. single phase 13,800/2300-v. transformers. The low side of these transformers ties in through 1200-amp. oil circuit breakers and disconnect switches to the 2300-v. generator bus of the oil station. Leads are also taken from the main 13,800-v. bus to two banks of 500-kw., 13,800/600-v. transformers which supply the two rotary converters carrying the local traction load. These 500-kw. G. E. synchronous converters located on the turbine room floor operate at 1200 r.p.m. and supply 834 amp. each at 600 v. to the d.c. lines.

As the station grows, it is contemplated that the next addition will be a larger unit which will probably replace two or three of the smaller capacity generators now in the old plant.

In order to meet the increased cost of operation, French coal mining companies have given special attention to mechanical equipment suited to the conditions in French mines which has resulted in the increase in the percentage of coal produced by machines in one district from 4.27 per cent in 1913 to 16 per cent in 1922, says Chester Lloyd Jones, Commercial Attache, Paris, in a report to the Department of Commerce. The character of the deposits is such that certain types of coal mining machinery as used in the United States will not always work with efficiency. Nevertheless in the Pas-de-Calais and in the Nord marked advance has been made in recent years. In the Pas-de-Calais there are two American machines of special type and one bar coal cutter in use or under trial. The most successful type employed is that of the mechanical pick-hammer. Of these there were in use in 1911 only 743, in 1913, 1,392; but in 1922, 2,872 were employed. Perforating hammers of the hand type have also become prominent, the number in use having risen from 1,878 in 1913 to 2,343 in 1922.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. Approximately, we say that every foot elevation is equal to ½-lb. pressure per square inch; this allows for ordinary friction.

Unit System for Pulverized Coal

IN REMODELED PLANTS, UNIT SYSTEM HAS ADVANTAGES. RESULTS OF TESTS. BY S. C. MARTIN

TWO general types of powdered fuel burning equipment are in use at the present time. These are the multiple or storage system, and the unit or direct system. In the former the fuel is first dried, then pulverized, and finally stored in tanks or hoppers from which it is withdrawn as required for use in the furnace. In the latter system the fuel may be fed directly to the pulverizer without being dried, the fine material being removed from the machine as fast as it is produced and conveyed immediately to the furnace and burned. Each system has its own particular field in which it excels and these overlap to a certain extent.

The unit or direct system possesses the advantages of low first cost, simplicity of operation, flexibility, and ease of installation; and it occupies comparatively little floor space. It is especially adapted for installation in plants that are already in operation, where it is desired to equip one or more furnaces to burn pulverized coal without making extensive changes in order to accommodate the equipment. Additional units may then be added later without in any way interfering with the original installation. When installing a battery of these unit pulverizing machines, provision may be made for driving them from a line shaft, thus obviating the necessity for providing a separate motor for each machine and at the same time saving considerable floor space. When so arranged, it is desirable to employ some means for cutting out of line any particular machine when the furnace which it serves is not in operation. The size and number of machines necessary for any particular installation will depend upon the load conditions, as it is essential that the pulverizers have sufficient capacity to take care of peak loads with a considerable margin of safety. No difficulty should be experienced in meeting varying conditions of operation with a single machine of sufficient capacity provided the equipment has been properly installed and a reasonable amount of care is exercised in its operation.

Of the unit system for powdered coal the pulverizing machine comprises the principal part and consists in general of a pulverizing element in connection with a feeding device and one or more fans to supply the required amount of air for removing the fine material from the machine and conveying it to the furnace. The total amount of air admitted with the fuel may be mixed with it at any point in its passage from the pulverizer to the burner outlet.

Regulation of the fuel supplied to the furnace is generally dependent upon the amount of material fed to the machine and, when such is the case, the feeder becomes an important part of the apparatus, for the excellence of combustion and the close regulation of the furnace temperature is then dependent upon the successful performance of this part of the equipment, therefore it should be capable of exercising quick and accurate control over the amount of material entering the machine regardless of the physical condition of this material.

In any case, the feeder should be adapted to the class of material it is intended to handle and its construction should be simple and rugged. Regulation of the total amount of air that is to be mixed with the fuel before it is burned is of equal importance with fuel regulation if the highest furnace efficiency is to be realized and it is desirable that the equipment be so designed that the ratio of fuel and air in the mixture may be controlled automatically if desired. Coal containing a large percentage of moisture may be successfully pulverized in the unit type of machine, and this feature is desirable when the size of the installation does not warrant the expense of drying the coal, or where there is an excess of moisture present for only a short time.

Pulverizing machines used with the unit system are built in capacities ranging from a few hundred pounds to several tons of powdered coal per hour delivered to the furnace. Only a little attention and no special training is required by the fireman to operate the equipment.

RETURN TUBULAR BOILER SERVED BY UNIT SYSTEM FOR PULVERIZED COAL

Power plants equipped with the unit pulverized coal system, properly installed, have been operated with good overall efficiency, the following tests made on an installation of this type indicating what results may be expected.

RESULTS OF TESTS OF UNIT POWDERED COAL SYSTEM

Test of.....No. 15 Stirling boiler
Kind of furnace.....
.....Special for powdered coal and blast furnace gas
Kind and size of coal.....Ideal nut and slack

AVERAGE PRESSURES, TEMPERATURES, ETC.

Steam pressure by gage.....130 lb.
Temperature of feed water entering boiler.....84 deg. F.

Temperature of escaping gases leaving boiler..470 deg. F.
Force of draft between damper and boiler..0.02 to 0.03 in.

TOTAL QUANTITIES

Weight of coal as fired.....10,838 lb.
Percentage of moisture in coal.....2.05
Total weight of dry coal consumed.....10,616 lb.
Total ash and refuse (by coal analysis).....2,486 lb.
Percentage of ash and refuse in dry coal.....23.42
Total weight of water fed to boiler.....78,087 lb.
Total water evaporated, corrected for moisture in steam .....78,087 lb.
Total equivalent evaporation from and at 212 deg. .....91,720 lb.

HOURLY QUANTITIES AND RATES

Dry coal consumed per hour.....2,123 lb.
Water evaporated per hour corrected for quality of steam .....15,617 lb.
Equivalent evaporation per hour from and at 212 deg. .....18,348 lb.
Equivalent evaporation per hour from and at 212 deg. per sq. ft. of water heating surface.....4,025 lb.

CAPACITY

Evaporation per hour from and at 212 deg.....18,348 lb.
Boiler horsepower developed.....531.6 hp.
Rated capacity, in evaporation from and at 212 deg. per hr. .....15,766 lb.
Rated boiler horsepower (based on A. S. M. E. code of 1015).....457 hp.
Percentage of rated capacity developed.....116

ECONOMY RESULTS

Water fed per pound of coal fired.....7.20 lb.
Water evaporated per pound of dry coal.....7.355 lb.
Equivalent evaporation from and at 212 deg. per pound of dry coal.....6.63 lb.
Equivalent evaporation from and at 212 deg. per pound of combustible.....11.28 lb.

EFFICIENCY

Calorific value of one pound of dry coal....10,290 B.t.u.
Calorific value of one pound of coal as fired..10,079 B.t.u.
Calorific value of one pound of combustible..13,523 B.t.u.
Efficiency of boiler and furnace.....80.94 per cent
Efficiency of boiler and furnace (coal as fired)..... .....83.08 per cent
Factor of evaporation.....1.1746
Average CO_2.....14.2 per cent

RESULTS OF TEST, USING PULVERIZED LIGNITE FUEL

Test of.....No. 11 Stirling boiler
Kind of furnace..... .....Special for powdered coal and blast gas furnace
Kind and size of coal.....Lignite (Puritan mine)

AVERAGE TEMPERATURES, PRESSURES, ETC.

Steam pressure by gage.....127.3 lb.
Temperature of feed water entering boiler.....101.5 deg.
Temperature of escaping gases leaving boiler.....575 deg.
Force of draft in furnace.....0.02 to 0.03 in.

TOTAL QUANTITIES

Weight of coal as fired.....12,404 lb.
Percentage of moisture in coal.....25.1
Total weight of dry coal consumed.....9,290 lb.
Total ash and refuse.....398 lb.
Percentage of ash and refuse in dry coal....4.29 per cent
Total weight of water fed to the boiler.....78,890 lb.
Total water evaporated, corrected for moisture in steam .....78,890 lb.
Total equivalent evaporation from and at 212 deg. .....91,276 lb.

HOURLY QUANTITIES AND RATES

Dry coal consumed per hour.....1,850 lb.
Water evaporated per hour corrected for quality of steam .....15,778 lb.
Equivalent evaporation per hour from and at 212 deg. .....18,255 lb.
Equivalent evaporation per hour from and at 212 deg. per sq. ft. of water heating surface.....4.00 lb.

CAPACITIES

Evaporation per hour from and at 212 deg.....18,255 lb.
Boiler horsepower developed.....529 hp.
Rated capacity, in evaporation from and at 212 deg. per hr. .....15,766 lb.
Rated boiler horsepower.....457 hp.
Percentage of rated capacity developed.....115.7

ECONOMY RESULTS

Water fed per pound of coal fired.....6.36 lb.
Water evaporated per pound of dry coal.....8.49 lb.
Equivalent evaporation from and at 212 deg. per lb. of dry coal.....9.86 lb.
Equivalent evaporation from and at 212 deg. per pound of combustible.....10.26 lb.

EFFICIENCY

Calorific value of one pound of dry coal.....12,400 B.t.u.
Calorific value of one pound of combustible..12,955 B.t.u.
Efficiency of boiler and furnace.....76.84 per cent

COST OF EVAPORATION

Cost of coal per ton of 2000 lb. delivered in boiler room $2.90
Cost of coal required for evaporating 1000 lb. of water from and at 212 deg.....$0.197
Factor of evaporation.....1.157
Average CO_2.....15.0 per cent
Coal as fired per boiler horsepower.....4.69 lb.

An installation of the unit system for pulverized coal is shown in the accompanying illustration. The pulverizer is of 3000 lb. per hr. capacity, driven by a direct connected motor and delivering pulverized coal to the furnace of an 84-in. by 20-ft., 250-hp. horizontal return-tubular boiler. The coal hopper and feeder are shown at the left, and the fan and damper for regulating the air supply at the right. The burner is located in the front wall of the furnace.

WATER in contact with saturated steam has the same temperature as the steam itself. Water introduced into superheated steam will be vaporized until the steam becomes saturated, and its temperature becomes that due its pressure. Cold water, or water at a lower temperature than that of the steam introduced into saturated steam, will condense some of it, thus lowering both the temperature and pressure of the rest until the temperature again equals that due its pressure.

Problems in Boiler Furnace Design*

CHANGES IN STOKER DESIGN, HIGH RATINGS, HIGH CAPACITIES, ETC., INTRODUCE PROBLEMS IN FURNACE DESIGN. BY EDWIN B. RICKETTS

IF THE PROBLEM of the furnace designer were simply to produce a furnace having the highest possible efficiency he would not be confronted with an extremely difficult task because it would be hard to surpass the work of that unknown Chinese engineer who used his fire to cook his dinner and afterward passed the products of combustion through brick flues in his bed, thus antidating Henry Ford by some 3000 yr. in burning his fuel twice. If our problem were simply to produce high capacity, again, we have ample precedent among the ancients for the book of Daniel describes a furnace built for King Nebucadnezzar which was operated for a considerable period at 700 per cent rating. The efficiency of this furnace was low and according to the record it was rather hard on the firemen but it suited the King and nobody else mattered.

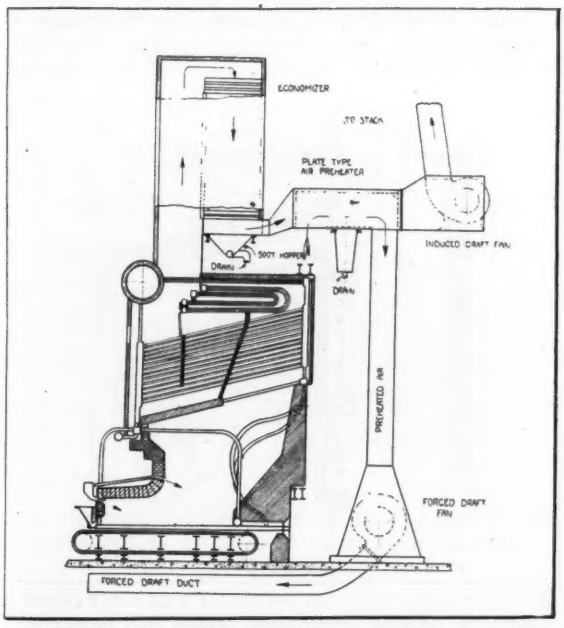


FIG. 1. PLATE TYPE AIR PREHEATER INSTALLATION AT CALUMET STATION

Our problem, is therefore, not primarily to design a furnace which will have high efficiency, nor can we rest content when we have produced a furnace which combines high efficiency with high capacity; our problem is so to design our furnaces that, when operated in conjunction with the other apparatus in the plant, we will be enabled, while maintaining the desired continuity of service, to produce the largest number of salable kilowatt-hours for a dollar, when fixed and operating charges are considered.

It will be manifestly impossible in this paper to cover adequately the whole field of furnace design, but it will be my purpose to present the present status of some of the more important problems which confront the furnace designer today.

As regards coal burning equipment, the best test records to date show that, given conditions favorable to the type of apparatus used, there is little, if any, difference in the efficiency or capacity obtainable when using powdered coal or stokers.

Efforts of manufacturers during the past year have been largely devoted to the production of apparatus capable of higher sustained ratings than have heretofore been considered practicable. While some of these so-called super coal burners are still suffering from the pains incident to too rapid growth, their performance on the whole has been very satisfactory. A number of installations, both of stokers and powdered coal, have been operated for considerable periods at ratings of 400 to 500 per cent.

Modern boiler furnaces occupying all the space under the boiler, together with the almost universal demand for the highest obtainable efficiency, have presented a number of new problems to the furnace designer. Among these problems are:

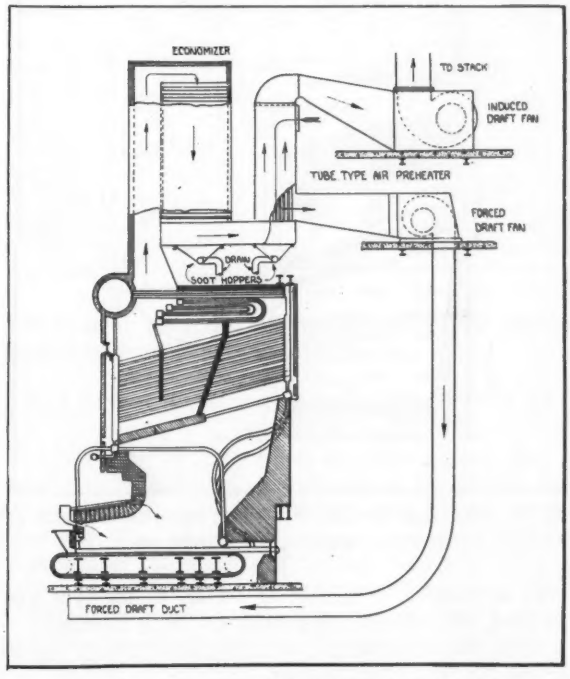


FIG. 2. TUBE TYPE PREHEATER AT CALUMET

THE VALUE OF AIR HEATERS

While the possibilities of increased boiler efficiency through the use of preheated air for combustion has long been realized by American engineers, the economies obtainable by the use of air preheaters did not appear particularly attractive until the rise in coal prices had greatly increased the value in dollars of our chimney losses. The apparent attractiveness of the air heater has been further increased in stations where multi-stage bleeding has been adopted for heating feed water because in such stations economizers are seriously limited in the quantity of heat which they can absorb from the flue gases.

In the accompanying table are given the test results of a number of air heaters which have recently been installed

* Paper presented before the Metropolitan section of the A. S. M. E.

in this country and in Europe, indicating some of the economic possibilities of this apparatus.

In analyzing these test results, we should keep in mind the fact that this apparatus is new to the operators and may not have been tested under the most favorable conditions; on the other hand, the heaters were all new and serious operating and maintenance troubles may develop later. We should, consequently, regard these test data as preliminary only, withholding final judgment until more complete returns are available.

Two types of air heaters now in use in this country are shown in Figs. 1 and 2.

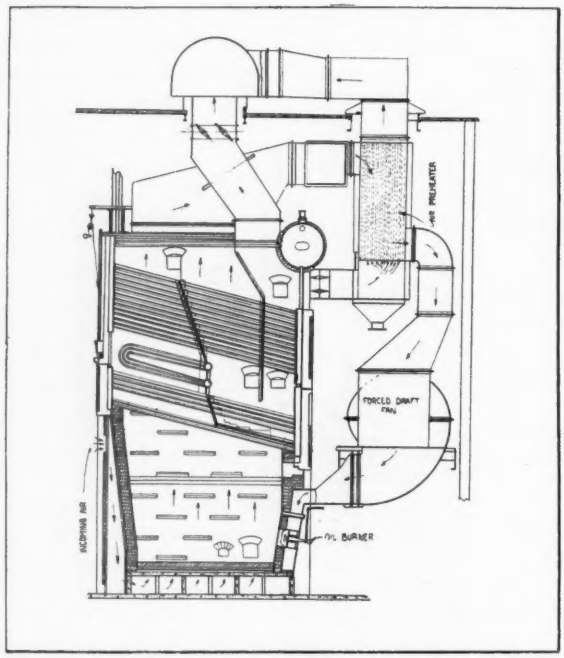


FIG. 3. OIL FIRED BOILER WITH AIR PREHEATER USED BY HOUSTON LIGHTING & POWER CO.

In addition to a number of heaters of the type just described, the following air heaters are being installed:

International Paper Co.—6 Ljungstrom rotary heaters for 450 deg. F. air temperature.

New York Edison Co.—1 Prat plate type heater for 400 deg. F. air temperature.

Commonwealth Edison Co.—1 Fin tube type heater.

Consumers Power Co.—1 Fin tube type heater.

Test data will probably be available on all these heaters during the coming year.

In view of the widespread interest in air heaters at the present time it may be well to review briefly some of the reasons for and against the use of this apparatus in central stations. The air heater affords a means of returning to the cycle a considerable quantity of low level heat which would otherwise be largely wasted. Consequently, the use of this apparatus should be carefully considered in the design of central stations. Generally speaking, that central station will be thermally most efficient which heats the feed water to approximately the temperature of the water in the boiler and at the same time preheats the air for combustion either by means of bled steam or flue gases to a temperature approaching that at which the flue gases leave the boiler, and the maximum return of low level heat can be obtained only when both feed water and air are heated to a relatively high temperature. The air heater has been used in Europe for many years but a careful review of technical literature, together with talks with European and American engineers who have studied the situation abroad, reveals the fact that there is little definite information available on the actual economic performance of air heaters in Europe. This lack of information is due to the fact that air heaters have only recently been applied to large central stations. Most of the installations so far have been of such a size relative to the boiler as not to preheat the air to a temperature above 250 deg. F. These heaters have been installed either following an economizer or in such a way as to absorb only a small part of the flue gas heat. Consequently, little operating data on the effect of high temperature on stoker and refractory maintenance is available. The information at hand indicates that air heated to not over 250 deg. will usually cause no serious trouble with either stokers or brick work. A few installations have been made where the air was heated to from 400 to 500 deg. F. One of these was an experimental installation in France on which some extensive tests were made by

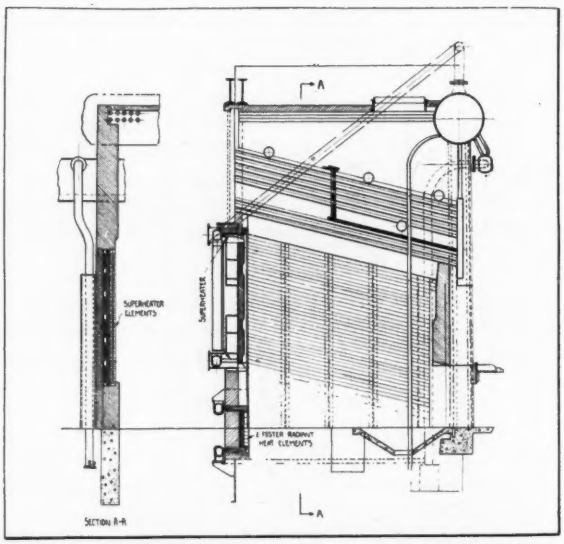


FIG. 4. SECTION THROUGH BOILER AT THE SAGINAW RIVER STATION OF THE CONSUMERS POWER CO., SHOWING FOSTER RADIANT HEAT ELEMENTS

Monsieur Bosack of the French Babcock & Wilcox Co. In this installation the air was heated to about 450 deg. and it was found that when using a coal having ash of a high fusing temperature, no serious difficulties were experienced but when ordinary low fusing ash coal was used, the clinker troubles were very largely multiplied.

At the North Tees Power Station in England, air heaters have been installed for preheating the air to about 300 deg. Serious difficulties have been reported on both brick work and stokers from this installation. The information available is not definite as to the part played by preheated air in the troubles at this plant.

In this country the only installation using highly preheated air is one of type "B" stokers under oil stills in the Chicago District burning Illinois coal with air at a temperature of about 500 deg. On this installation serious clinker troubles have been experienced whenever high ratings have been attempted.

Indications are that heated air has in many cases advantages other than the straight return of a certain number of B.t.u. to the cycle. Those advantages are the more rapid combustion of the fuel usually accompanied by a reduction in excess air, in the carbon rejected with the ash, and the length of the flame. The beneficial effect of heated air will probably prove more pronounced with those relatively low grade fuels, high in moisture and ash, which in many cases will not produce a furnace temperature sufficiently high to make clinker troubles even with highly preheated air.

An air heater having a surface infinitely large would, in few cases, be able to absorb in excess of 80 per cent of the heat in the flue gases, because in most cases 20 per cent of the weight of gases passing up the stack is accounted for by infiltration above the grates and through the flue connection.

It is hoped that the information which will be obtained on installations now being made in this country during the coming year will make possible a much more definite appraisal of the value of heating combustion air than can be done at the present time. Large scale installations of air heaters will hardly be advisable until the advantages of this apparatus have been definitely established under the

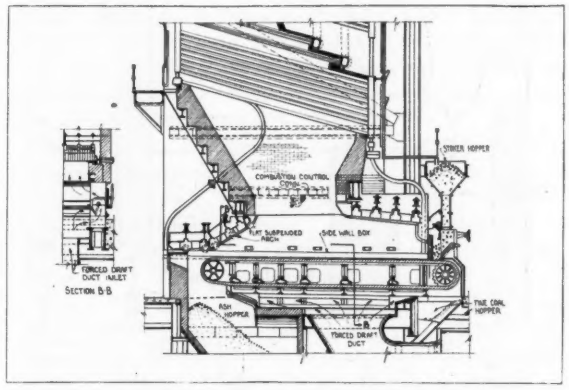


FIG. 5. SECTION THROUGH BOILER SHOWING REVERSED ARCH CONSTRUCTION AT WABASH RIVER STATION OF THE INDIANA ELECTRIC CORPORATION

conditions of fuel, stoker, furnace, etc., which obtain in the plants under consideration.

Materials for Furnace Wall Construction

In his effort to produce a furnace for high capacity and efficiency, the designer is handicapped by the characteristics of the refractories commercially available. There is little difficulty in selecting refractories which will not fail by fusion under the ordinary conditions of boiler operation but so far no firebrick has been demonstrated which will resist the slag action of all kinds of coal at high temperatures. On account of the wide variations in ash composition of various coals, the prospects of an early solution of this problem are not very bright. Rumors come to us from time to time that a universal super-refractory is about to become available which will solve all our problems but so far these claims have not been demonstrated and if we wish to get a furnace which will last under modern operating conditions, it will frequently be necessary to protect the furnace lining from the full effects of temperature and slag erosion.

The necessity for some artificial cooling of furnace walls was first felt in connection with pulverized coal furnaces and a satisfactory solution for this type of equipment has been found in the use of air-cooled walls. This type of construction, however, is not well adapted to stoker practice because, if fan pressure is put in the hollow walls, excessive leakage into the furnace will occur and if the air space is put under a suction, leakage will occur from the furnace to the air chambers, thus increasing the tendency to destroy the refractories.

Some boiler furnaces have recently been constructed having extensive water cooling in the side walls. This, however, is a subject in itself and I will not discuss it other

SUMMARY OF AIR HEATER DESIGN

SUMMARY OF AIR HEATER DATA
FIGURES GIVEN ARE AVERAGES OF TESTS

	UNITED STATES				FOREIGN		
LOCATION	COLFAX STA. DUQUESNE LIGHT CO.	BOILER NO 6, CALUMET STATION COMMONWEALTH EDISON CO. CHICAGO, ILL.	BOILER NO 6, CALUMET STATION COMMONWEALTH EDISON CO. CHICAGO, ILL.	BOILER NO 13, NORTHWEST STATION KANSAS CITY LIGHT AND POWER CO.	EARLSAND	RIVERSIDE STATION BENOIST AND CO.	THE HARNE, HOLLAND MARINE MUNICIPAL POWER PLANT
MANUFACTURER	COMBUSTION ENG'G CO.	COMBUSTION ENG'G CO.	BABCOCK AND WILCOX CO.	COMBUSTION ENG'G CO.	JAS. HENDERSON & CO.	WASSEN EPHILE PRINT-DANIEL	WASSEN EPHILE PRINT-DANIEL
TYPE	PLATE	PLATE	TUBE	PLATE	HENDERSON-LANGSTROM	"THERMIX"	"THERMIX"
BOILER SURFACE, SQ. FT.	22,914	19,089	19,989	12,743	900*	1980	6725
SUPERHEATER SURFACE, SQ. FT.	2,999	4,092	4,092	5,748	–	–	–
ECONOMIZER SURFACE, SQ. FT.	–	9,720	9,720	8,100	–	–	5130
AIR HEATER SURFACE, SQ. FT.	11,880	9,000	8,934	9,500	–	1306	7525
TEMP. OF GAS, DEG. F AIR HEATER INLET	482°	535.8°	594.4°	595°	595°	590°	592°
TEMP. OF GAS, DEG. F AIR HEATER OUTLET	309°	264.8°	310.4°	334°	250°	–	316.4°
TEMP. OF AIR, DEG. F AIR HEATER INLET	108°	71.8°	63.5°	79°	–	62.6°	78.8°
TEMP. OF AIR, DEG. F AIR HEATER OUTLET	229° ①	181.8°	153.1°	168°	456°	193.4°	197°
WEIGHT OF GAS, THRU AIR HEATER, LBS. PER HOUR	171,067	175,500	–	–	–	–	–
GAIN IN EFFICIENCY DUE TO HEAT ABSORPTION, %	5.8%	4.85%	4.72%	4.99%	3.6%	2.7%	2.2%
GAIN IN EFFICIENCY DUE TO BETTER COMBUSTION, %	3.14%	–	–	12.5%	13.4%	10.5%	4.3%

① AT FAN DISCHARGE * SCOTCH MARINE BOILER

than to show a diagram illustrating some of the arrangements used for this purpose. See Fig. 4.

The Effect of High Combustion Efficiency on Superheat

In a number of plants where oil, powdered coal or more modern stoker equipment has superseded less efficient fuel burning equipment, the superheat has been lowered in some cases more than 50 per cent, necessitating large increases in surface or the removal of the superheater to a higher temperature location. In many cases it has been found practically impossible to obtain the desired steam temperature with the superheater located above the tube bank.

This loss in superheat with increased combustion efficiency is a result of the reduction in excess air and consequent increase in heat absorption in the first pass of the boiler and of the lessening of secondary combustion incident to better gas mixtures in the furnace. It is not generally realized that the combustion of one per cent of CO above the tube bank may increase the superheat 50 to 60 deg.

The Mixing of Boiler Furnace Gases

With the development of stokers extending across the full length of the boiler the tendency to stratified flow of the furnace gases has been greatly accentuated. The gases rich in hydrocarbons and deficient in oxygen which rise from the front of a stoker have very little tendency to mix with the stream of gas containing large amounts of excess air coming from the thinner part of the fuel bed at the rear. These two streams mix after a fashion in the tube bank producing secondary combustion with its accompanying high exit gas temperature. In some cases this mixing does not take place until after the gases have been cooled

below the ignition point, causing losses due to CO and unconsumed hydrocarbons.

The necessity for some means of mixing the gases was first realized in connection with chain grate stokers and a number of mixing arch arrangements have been successfully applied to this type of stoker. This matter was very ably presented by Mr. Mumford and others at the January 25th meeting of this section (printed in Power Plant Engineering March 1 issue, page 272.) I will not discuss gas mixing with chain grates other than to refer you to Fig. 5 which illustrates the application of reverse arch construction to mid-western fuels.

Practically nothing has been done so far in the matter of mixing gases on underfeed stokers and the need for mixing is almost as great as it is with chain grate. It is generally felt by engineers operating underfeed stokers that the application of arches to this type of stoker is highly undesirable on account of maintenance costs.

There is, therefore, an open field for inventive genius in providing a furnace design which will adequately mix the gases from this type of stoker.

To my mind, there is no field today in the combustion game in which the possibilities of improvement in efficiency are so large as they are in the proper mixing of furnace gases. Many of us have thought that the solution lay in high furnaces but after an examination of a number of modern furnaces fired by both stoker and powdered coal, in which the tube bank was set 20 ft. or more above the floor of the furnace and having seen the flames carrying to the top of the first pass, I have come to the conclusion that it will not be practicable to build a furnace high enough to produce complete combustion before the tubes are reached unless some means are provided for bringing the rich and lean gas streams together.

Where the ratings are moderate, say not over 250 per cent, with modern setting heights, poor mixing will usually make itself felt only through higher flue temperatures but with the higher ratings which present day practice demands, frequently losses of relatively large magnitude are realized, due to carbon monoxide and hydrocarbons passing unburned up the stack.

Heated combustion air will undoubtedly help to shorten the flame length but I am loath to believe some of the extravagant claims of 15 per cent or more saving made by some of the European air heater enthusiasts.

We are passing now through a period when ideas on furnace design are changing rapidly; many new schemes are being tried but on most of them the experience has not been sufficient for their value to be definitely stated.

In the twenty-odd years that I have followed the operation and design of boiler furnaces there never has been a time when I was less confident of my ability to design a boiler furnace than I am today. I am bringing to you my problems in the hope that Solomon was right when he said, "In the multitude of Councillors there is wisdom."

To PRESERVE wire rope, apply raw linseed oil with a piece of sheepskin; wool inside; or mix the oil with equal parts of Spanish brown and lampblack. To preserve wire rope under ground or in water, take mineral or vegetable tar, add 1 bu. of fresh slaked lime to 1 bbl. of tar, which will neutralize the acid; boil it well, then saturate the rope with the boiling tar.

Burning Mixtures of Lignite and Bituminous

DISADVANTAGES COUNTERACTED BY QUALITIES OF THE OTHER. BY ALBERT CANFIELD

DURING the last few years engineers have witnessed a growing tendency throughout the country to utilize the lower grade fuels. The sub-bituminous and lignite coals in particular have come to the front, due largely to the increase in cost of the higher grade bituminous coal. Notwithstanding the growing popularity of the lower grade fuels, much still remains to be learned regarding the most efficient method of utilizing them. Experiments are now

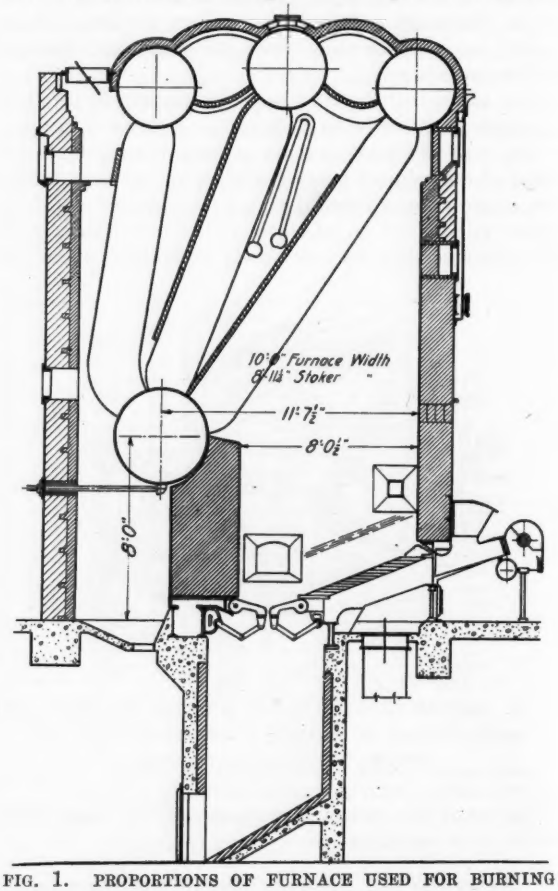


FIG. 1. PROPORTIONS OF FURNACE USED FOR BURNING MIXED LIGNITE AND BITUMINOUS

being conducted on drying and pulverizing Dakota lignite, to the end that this fuel, mined in the vast beds of the Northwest, may be more efficiently and more generally utilized in larger steam generating stations.

North Dakota lignite may be burned with satisfactory results under certain conditions. Its high moisture content (30 to 40 per cent) and its disintegrating property under the action of heat necessitates large grate areas, and when burned on underfeed or chain grate stokers, a long grate is essential to provide the time element required for evaporation of the moisture. When forced blast is employed, it is necessary to maintain relatively low undergrate air pressures to prevent the light, disintegrated fuel from being blown from the fuel bed.

In plants where the furnace design is unsuited to the burning of lignite alone, due to insufficient grate area or

other cause, satisfactory results may usually be obtained by mixing lignite with a coking, or low oxygen bituminous coal in a proportion depending upon the boiler rating required and the relative cost of the two fuels. When the mixture burns, the more readily combustible bituminous coal ignites early and in so doing assists in the rapid disintegration and moisture evaporation of the lignite. Furthermore, the coking action of the bituminous coal tends to prevent the lighter lignite fuel from being blown from the grates and by virtue of this, high undergrate air pressures may be carried with a corresponding high rate of combustion per square foot or grate area.

In the power plant of the State Mill and Elevator at Grand Forks, North Dakota, a series of experiments has been conducted during the past six months to determine the most economical ratio of lignite to be burned with Eastern bituminous. This plant is equipped with 400-hp. Stirling boilers and multiple retort underfeed stokers. The latter having a furnace depth of but 8 ft. and a projected grate area of but 72 sq. ft., are unsuited to the burning of lignite alone, except at low ratings. By mixing lignite with a coking bituminous coal in the proportion of 60 and 40 per cent, a reduction in the cost of steam generation amounting to about 12 per cent is effected, and continuous ratings as high as when burning bituminous alone are obtained.

An average daily steam load factor of 88 per cent in this plant offers an ideal condition for testing. Only slight changes in load occur either from day to day or from month to month. Throughout the tests, the operating conditions averaged as follows:

Rating .....120 per cent
Steam pressure .....180 lb. gage
Superheat .....190 deg.
Feed water temperature.....150 deg.

Figure 2 shows the average actual rates of evaporation obtained with various percentages of lignite.

Figure 3 is based upon data derived from Fig. 2 and

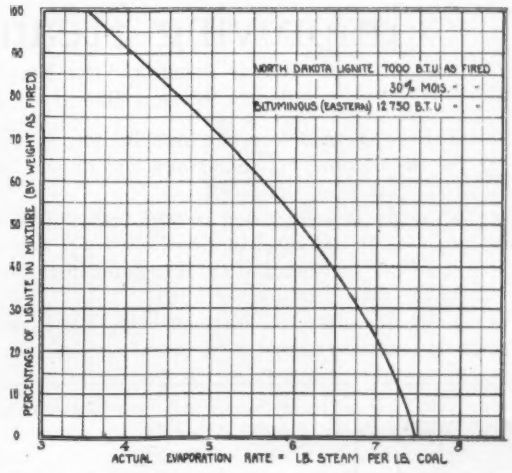

NORTH DAKOTA LIGNITE 7000 B.T.U. AS FIRED
30% MOIS. - -
BITUMINOUS (EASTERN) 12750 B.T.U. - -
PERCENTAGE OF LIGNITE IN MIXTURE (BY WEIGHT AS FIRED)
ACTUAL EVAPORATION RATE = LB. STEAM PER LB. COAL

FIG. 2. ACTUAL EVAPORATION DECREASES AS THE PERCENTAGE OF LIGNITE IN MIXTURE INCREASES

indicates the relative cost of evaporating a unit quantity of water when using various percentages of lignite, for various ratios of lignite cost to bituminous cost. A unit cost of 100 is used as representating the cost of evaporating a given quantity of water when burning Western Pennsylvania screenings having a heat content of approximately 12,750 B.t.u. as fired. This fuel is the same as that mixed with the lignite in the mixture tests.

Figure 4 was prepared from the curves in Fig. 3 by using the most economical fuel mixture for various ratios of lignite cost to bituminous cost.

While these charts are strictly applicable only for conditions similar to those existing in the plant for which they were prepared, they nevertheless serve as an indication of what may be expected in other plants similarly situated with respect to a supply of the lower grade and cheaper fuels.

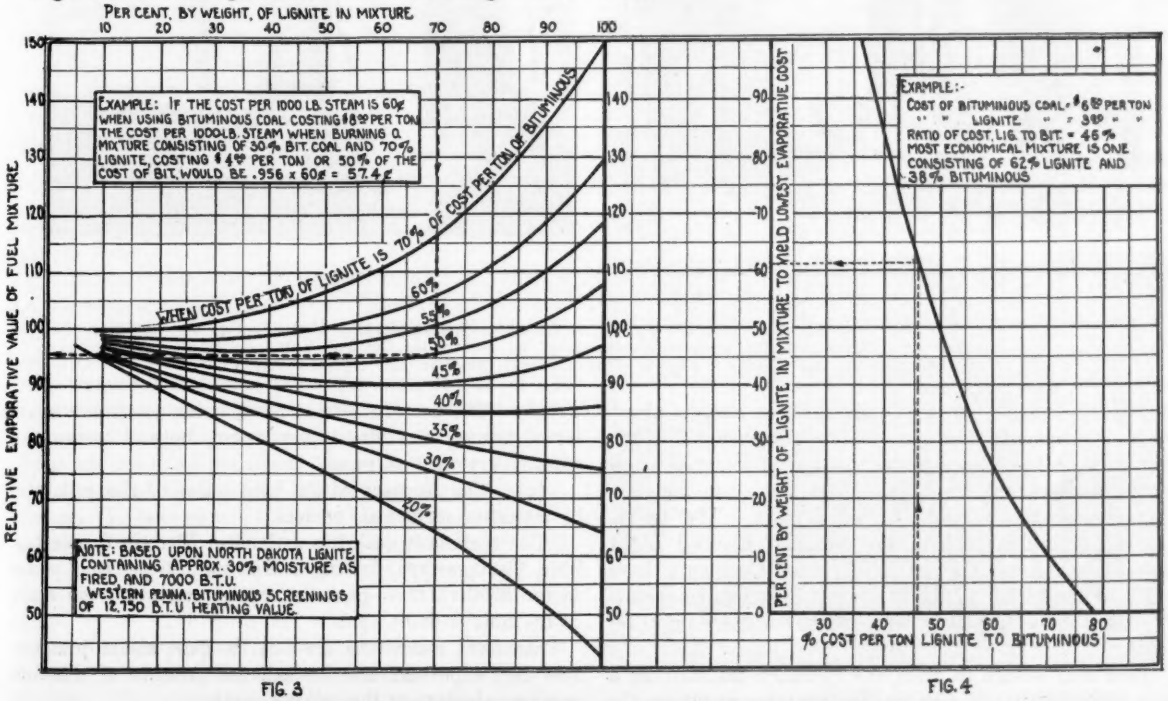

PER CENT. BY WEIGHT, OF LIGNITE IN MIXTURE
RELATIVE EVAPORATIVE VALUE OF FUEL MIXTURE
EXAMPLE: IF THE COST PER 1000 LB. STEAM IS 60¢ WHEN USING BITUMINOUS COAL COSTING $8.00 PER TON THE COST PER 1000 LB. STEAM WHEN BURNING A MIXTURE CONSISTING OF 30% BIT. COAL AND 70% LIGNITE, COSTING $4.00 PER TON OR 50% OF THE COST OF BIT. WOULD BE .956 x 60¢ = 57.4¢
WHEN COST PER TON OF LIGNITE IS 70% OF COST PER TON OF BITUMINOUS
60%
55%
50%
45%
40%
35%
30%
20%
NOTE: BASED UPON NORTH DAKOTA LIGNITE CONTAINING APPROX. 30% MOISTURE AS FIRED, AND 7000 B.T.U. WESTERN PENNA. BITUMINOUS SCREENINGS OF 12,750 B.T.U. HEATING VALUE.
FIG. 3
PER CENT BY WEIGHT OF LIGNITE IN MIXTURE TO YIELD LOWEST EVAPORATIVE COST
EXAMPLE:-
COST OF BITUMINOUS COAL - $6.00 PER TON
" " LIGNITE " " 3.00 " "
RATIO OF COST, LIG. TO BIT. = 46%
MOST ECONOMICAL MIXTURE IS ONE CONSISTING OF 62% LIGNITE AND 38% BITUMINOUS
% COST PER TON LIGNITE TO BITUMINOUS
FIG. 4

FIG. 3. CHART FOR DETERMINING ECONOMIC VALUE OF MIXED FUEL

FIG. 4. PROPER MIXTURE FOR LOWEST EVAPORATION COST IS GIVEN BY THIS CURVE

Improving Steam Turbine Operation

STEAM TURBINE WITH ELECTRICALLY OPERATED AUXILIARIES AT BOONE STATION HAS HIGH ECONOMY. BY JOHN M. DRABELLE

AT THE BOONE Station of the Iowa Railway & Light Co. the installation of a rather new and unique type of turbine has just been completed.

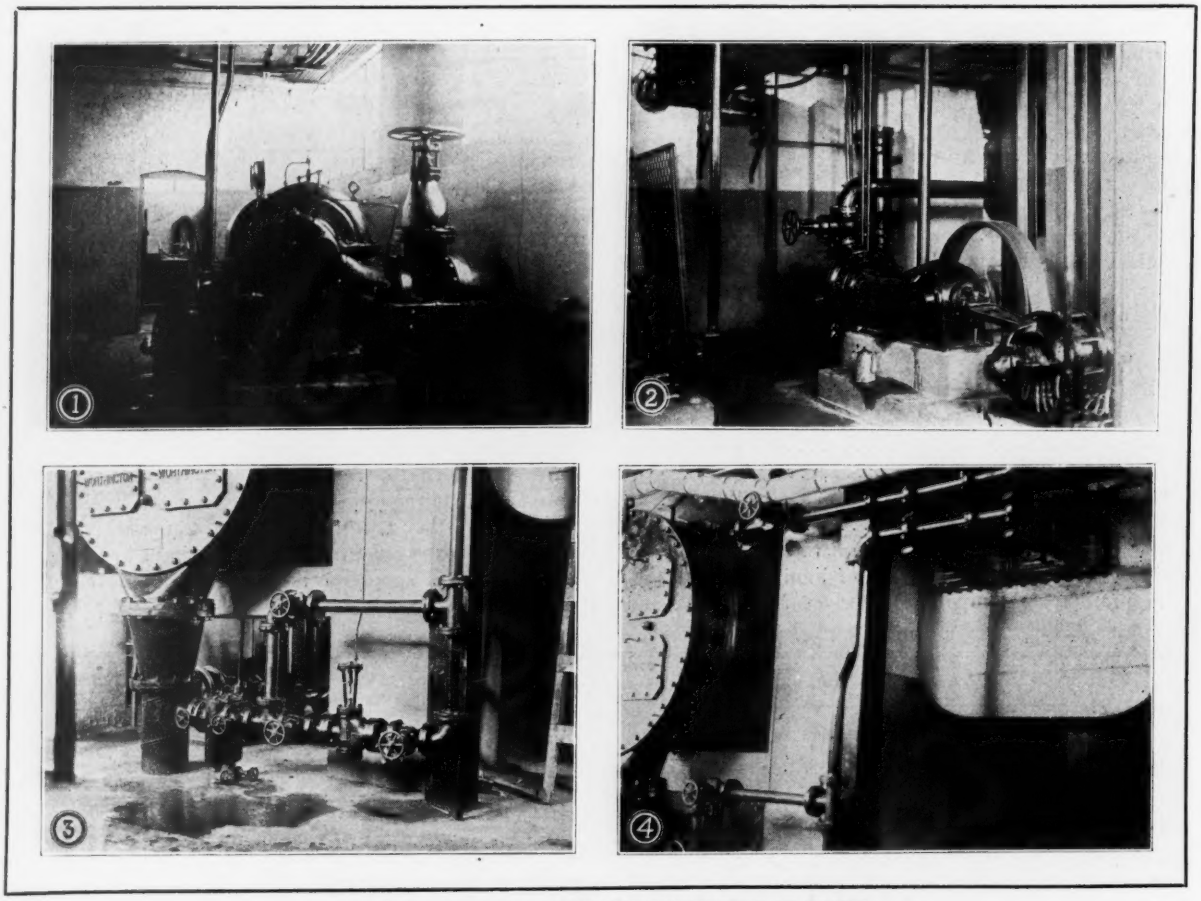
Because of the steadily rising cost of fuel, it has become necessary for the Central Station Industry to subject its boiler plant performance and the economies in the turbine part of the station to close scrutiny.

Considerable progress has been made by the turbine manufacturers during the past 5 yr. in reducing the water rates of small prime movers. This has been brought about by the refinement of design and workmanship. Much research work has been done on the flow of steam through nozzles, buckets and diaphragms that has given the data necessary for the redesign of these parts. The Prime Movers Committee of both the National Electric Light Association and the Association of Edison Companies have both contributed to the manufacturers considerable operating data that has helped to point the way to these improvements.

Iowa coal is high in price, the operators maintaining a price differential that with the freight rates precludes the use of Illinois coal much west of Cedar Rapids in the central belt of the state. We had brought the operation of our boiler plants, unless we should completely redesign and change over to powdered fuel, to about the highest point of commercial efficiency possible. To bring about further reductions in operating expenses, the only point left was the generating room.

The unique points of this installation are:

(a) The use of a 15-stage turbine.



FIGS. 1-4. VIEWS OF AUXILIARY EQUIPMENT AT BOONE

Fig. 1. The Circulating Pump; Driven by a Variable Speed Electric Motor. Fig. 2. Feather Valve Rotative Dry Vacuum Pump. Fig. 3. Automatic Control Valve on Raw Water Section of Air Cooler. Fig. 4. The General Electric Co. Surface Air Cooler

(b) The use of electric drive for the condenser auxiliaries, namely the circulating pump, hotwell pump and rotative dry vacuum pump.

(c) The recovery of the heat losses of the generator by means of surface air coolers.

The turbine installed is a General Electric Curtis turbine, 15-stage type, driving a 3500-kw., 80 per cent power factor 2300-v., three-phase, 60-cycle generator; the speed of the unit is 3600 r.p.m.

Standard conditions are 225 lb. gage steam pressure, 100 deg. superheat and an exhaust pressure of one-inch mercury absolute at the turbine nozzle.

Condensing equipment is of Worthington manufacture and consists of a surface condenser having a tube surface of 6250 sq. ft. The tubes are ¾-in. O. D. No. 18 gage 14 ft. long. The water velocity through the tubes is 4.3 ft. per sec. The circulating pump is a 12-in. volute double suction type rated at 5000 gal. per min., and driven by a 100-hp. variable speed 2300-v. motor. It should be noted here that spray ponds are used, consequently the horsepower required for circulating water is considerably more than that required for a plant located on a stream or lake. The vacuum pump is a single-cylinder, two-stage, 18 by 9-in. pump, driven by a 15-hp. variable speed motor while the hotwell pump is the vented two-stage type built to handle 115 gal. per min. against an external head of 34 ft. It is driven by a 7.5-hp., 1200-r.p.m. constant speed motor.

Generator cooling is effected by means of a closed system of ventilation, i. e. the air for cooling the field and stator of the generator is circulated over and over again, giving up its heat to a surface air cooler. The use of this device offers several distinct advantages:

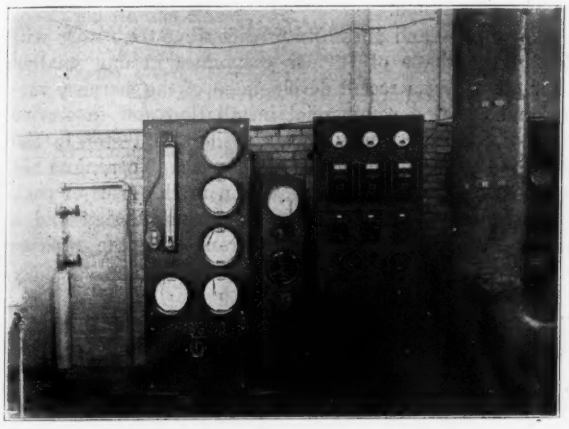


FIG. 5. THE GAGE BOARD, VENTURI METER AND ELECTRIC CONTROL PANEL

(1) Clean windings and air ducts in generator.

(2) Small amount of air in cooling system with small quantity of O_2, in case of a generator fire, this will quickly die out due to lack of O_2 to support combustion.

(3) The recovery of the generator core and copper losses as heat absorbed by the condensate passing through the main section cooler.

Preliminary checks of the performance of the surface air coolers show to date that approximately 1 per cent of the coal required to operate the unit is returned to the boiler plant.

For summer conditions when the temperature of the condensate is increased due to lower vacuum caused by higher circulating water temperatures, and also at less than ⅓ load and overload condition, the main section will not reduce the air to the required temperature for cooling the windings. To take care of this condition there is an auxiliary section of cooler. This is supplied with water from the condenser circulating system and the water supply for the auxiliary section is controlled by a thermostatically operated valve. The controller and valve equipment was designed for this purpose by the Foxboro Co. It consists of a sensitive bulb located in the discharge air duct of the generator. The thermometer element operates a valve

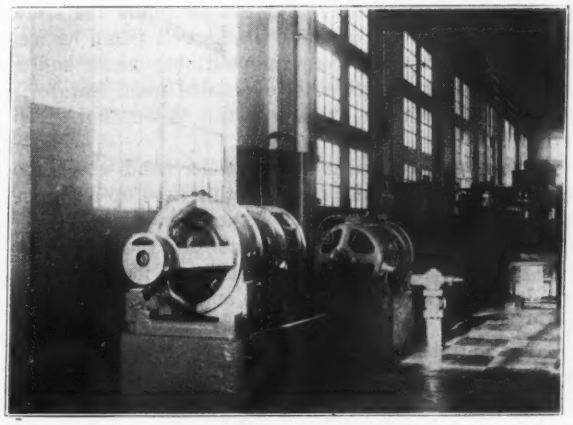


FIG. 6. EXCITER SETS

which admits and releases air to the air cylinder of the water supply valve. This valve is assembled "reversed" so that in case of a failure of the air supply the water valve will go open. As a further safeguard, another thermometer element is installed which is equipped with electrical contacts, so that in case the air temperature leaving the generator exceeds 145 deg. F. a Claxon horn sounds, warning the watch engineer. The air leaving the generator is held at a temperature of from 125 to 140 deg. F. as a maximum. By maintaining a fairly high heat head the maximum recovery is secured.

Structural features of the coolers will be of interest. The cooler consists of two "main" and two "auxiliary" sections. These are built up of Muntz metal tubes on which are wound helically a copper ribbon; this "Fin" increases materially the heat absorbing surface. The tubes are assembled between two-tube sheets of Muntz metal, one end of the tube being rolled in one sheet and the other packed with condenser tube packing and a ferrule. Water boxes are provided on each end and the water makes four passes through the cooler. The entire structure is assembled in a heavy angle iron frame.

Control equipment for the turbine auxiliaries is of the push button type. The control panel is located on the main engine room floor. For the circulating pump the equipment consists of one a.c. ammeter, one polyphase recording watthour meter, one start and stop push button and the controller for cutting in or out resistance in the

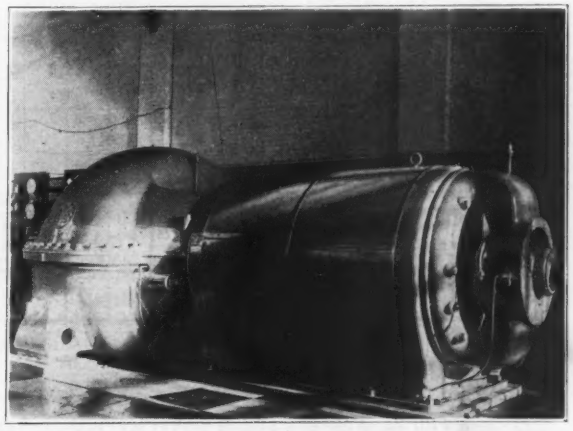


FIG. 7. THE 10,000-KW. TURBO GENERATOR

rotor circuit of the motor. For the air pump the same equipment is provided and for the hotwell pump an a.c. ammeter, one polyphase recording watthour meter and a start and stop push button. No variable speed feature is provided on the hotwell pump as this is constant speed service.

To start the equipment the controller hand wheels are first brought to the "off" position; this lines up an interlocked circuit so the unit may be started. The operator then pushes the button marked "start" and the unit comes up to speed at once. Full protection is provided for, overload, low voltage and reverse phase and partial phase voltage.

This control permits the watch engineer to start all the auxiliaries without taking a step and by merely pushing a button. The ammeter permits him to know just how much current is being taken by the motor and the watthour meters permit the station chief to maintain a careful check at all times on the performance of the auxiliaries.

In this installation the variable speed drive of circulating and air pumps was first developed by F. C. Chambers at the time he was mechanical and electrical engineer of the Des Moines City Railway. The remote control feature of the drive was first applied by the author to unit number five at the Iowa Railway & Light Co. Sixth Street Station at Cedar Rapids, Iowa.

In operating this system it is practice to run the circulating and the air pump at the lowest possible speed without loss in vacuum. In other words, a constant temperature rise through the surface condenser. The statistics below are for a 10,000-kw. unit equipped with such control:

Total generated kilowatt hours	3,882,000
Vacuum pump kilowatt hours	10,587
Hotwell pump kilowatt hours	6,558
Circulating pump kilowatt hours	46,169
Total auxiliary kilowatt hours	63,314
Vacuum pump	0.27 per cent total generated
Hotwell pump	0.17 per cent total generated
Circulating pump	1.17 per cent total generated
Total	1.63 per cent total generated

These figures will give you some idea of the economy of electric drive for turbine auxiliaries, for it must be borne in mind that this energy is supplied at the water rate of the main prime mover. The water rate of small steam turbines, even when used through reduction gears, would for the circulating pump have a rate of 40 lb. per b.hp.-hr.

Water rates of small prime movers ranging from 500 to 10,000 kw. in size, and particularly along in the 3500-kw. class, the sizes of turbine largely used in this state, it is now possible with steam pressures around 225 lb. and with 100 deg. superheat to obtain water rates ranging between 12½ and 13½ lb. at full load, depending on vacuum and size of unit selected.

It is unwise and unsafe to predict what the future will offer in the shape of further economies in our smaller power plants but a recent development of the mercury turbine and the first commercial installation now in service at Hartford, Conn., may be a considerable factor in the future reduction of power generator costs. There does not seem to be much hope of a reduction in the price of coal, so it will largely be a problem of turbine design and a further extension of the turbine ranges in the rankine cycle.

Power Plant Design and Operating Cost---III

Comparison of Costs Using Various Prime Movers Which are to Operate Non-Condensing and Which Will Use Saturated Steam

TWO SETS of cost data on the design and maintenance of a 1500-kw. central station have been published in past issues of Power Plant Engineering. The first covered the costs of a condensing plant which was operated with superheated steam; this appeared in the April 1 issue. The second set of costs, published in the April 15 issue, covered the design and maintenance costs of plants operating non-condensing and with superheated steam. The

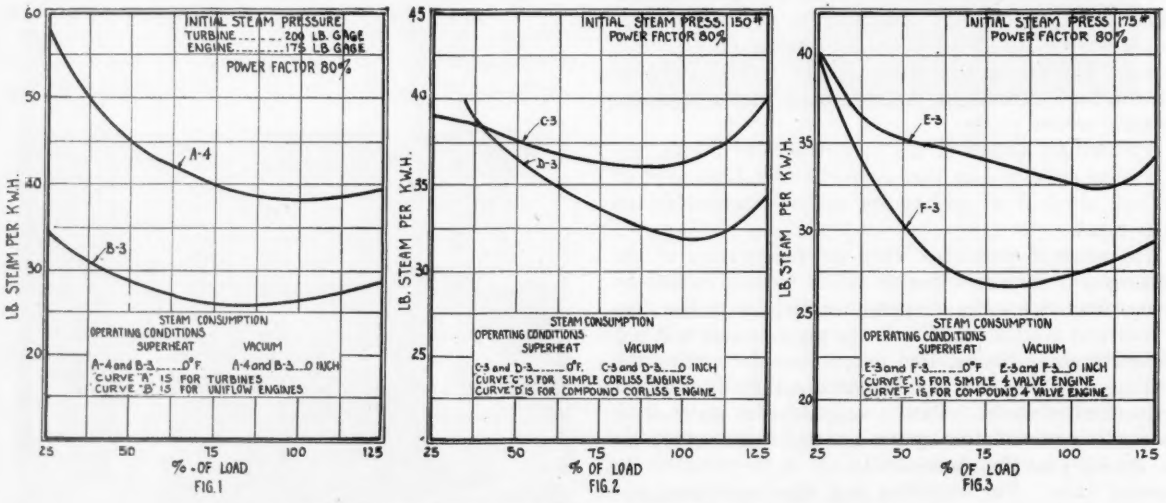


FIG. 1. AVERAGE STEAM CONSUMPTION OF A TURBINE AND A UNIFLOW STEAM ENGINE

FIG. 2. AVERAGE STEAM CONSUMPTION CURVES FOR SIMPLE AND COMPOUND CORLISS ENGINES

FIG. 3. AVERAGE STEAM CONSUMPTION CURVES FOR SIMPLE AND COMPOUND FOUR-VALVE ENGINES

data given in this third or last installment shows the comparative costs of design and maintenance of non-condensing plants operating without superheat, that is with saturated steam.

As in the two previous sets of problems the location of the plant is assumed to be near a supply of water which is adequate and of such quality that it is suitable for boiler feed purposes. Coal is to be delivered to the plants by rail. Costs covering the Diesel engine type of prime mover are not given for comparison with the non-condensing, saturated steam plants for the reason that these costs are more nearly comparable with the steam plant which is run condensing.

Building construction in all cases is assumed to be of steel frame work with brick filled walls. The construction costs are based on the price of labor and materials which

Investment and Operating Costs of a 1500-kw. Central Station Non-Condensing Plant with Saturated Steam

INVESTMENT COSTS

	Turbine Plant	Uniflow Engine Plant	Simple Four Valve Engine Plant	Compound Four Valve Engine Plant	Simple Corliss Engine Plant	Compound Corliss Engine Plant
Real Estate	$8,000.00	$8,000.00	$8,000.00	$8,000.00	$8,000.00	$8,000.00
Building	141,300.00	177,200.00	164,500.00	156,700.00	155,300.00	163,700.00
Boilers	61,800.00	47,200.00	51,700.00	43,200.00	54,100.00	50,000.00
Stokers	20,200.00	15,850.00	17,400.00	14,350.00	18,800.00	17,350.00
Piping	45,000.00	45,000.00	45,000.00	45,000.00	40,000.00	40,000.00
Generating Units	73,500.00	135,700.00	131,500.00	142,500.00	131,500.00	158,500.00
Switchboard	17,600.00	17,600.00	17,600.00	17,600.00	17,600.00	17,600.00
Wiring	13,200.00	13,200.00	13,200.00	13,200.00	13,200.00	13,200.00
Chimney and Flue	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00
Forced Draft Fans and Ducts	7,800.00	6,500.00	6,800.00	6,500.00	6,800.00	6,500.00
Coal and Ash Handling Equipment	35,250.00	35,250.00	35,250.00	35,250.00	35,250.00	35,250.00
Engine Room Crane	2,100.00	2,550.00	2,400.00	2,400.00	2,550.00	2,550.00
Feed Water Heater	3,000.00	2,500.00	2,700.00	2,500.00	2,700.00	2,500.00
Feed Pumps	4,800.00	4,300.00	4,500.00	4,010.00	4,500.00	4,300.00
Equipment Foundations	6,620.00	15,800.00	11,670.00	15,830.00	11,870.00	13,900.00
Oil Filters and Tanks	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00
Railroad Siding	2,550.00	2,550.00	2,550.00	2,550.00	2,550.00	2,550.00
Total	$463,220.00	549,700.00	$535,270.00	$530,090.00	$525,220.00	$556,400.00
Cost per kw. (1500 kw. Peak)	$308.81	$366.47	$356.85	$353.39	$350.15	$370.93

OPERATING COSTS

Load Factor 25%

Fuel	$100,100.00	$64,050.00	$72,975.00	$66,710.00	$76,125.00	$76,475.00
Labor	11,580.00	11,580.00	11,580.00	11,580.00	11,580.00	11,580.00
Lubricants	250.00	500.00	500.00	500.00	500.00	500.00
Supplies	3,300.00	3,800.00	3,900.00	3,800.00	4,000.00	3,800.00
Operating (Total)	$115,230.00	$79,930.00	$88,955.00	$82,590.00	$92,205.00	$92,355.00
Maintenance	$6,500.00	$7,500.00	$7,000.00	$7,000.00	$7,000.00	$7,000.00
Production (Total)	$121,730.00	$87,430.00	$95,955.00	$89,590.00	$99,205.00	$99,355.00
Fixed Charges 15%	69,483.00	82,455.00	80,291.00	79,514.00	78,783.00	83,460.00
Total Cost at Bus	$191,213.00	$169,885.00	$176,246.00	$169,104.00	$177,988.00	$182,815.00
Cost per kw-hr.						
Production	$0.0371	$0.0265	$0.0292	$0.0272	$0.0302	$0.0302
Fixed Charges	0.0211	0.0251	0.0244	0.0242	0.0240	0.0254
Total	$0.0582	$0.0516	$0.0536	$0.0514	$0.0542	$0.0556

Load Factor 50%

Fuel	$146,825.00	$105,000.00	$114,100.00	$100,100.00	$122,150.00	$117,250.00
Labor	12,260.00	12,660.00	12,660.00	12,660.00	12,660.00	12,660.00
Lubricants	300.00	550.00	550.00	550.00	550.00	550.00
Supplies	3,500.00	4,000.00	4,100.00	4,000.00	4,200.00	4,000.00
Operation (Total)	$162,885.00	$122,210.00	$131,410.00	$117,310.00	$139,560.00	$134,460.00
Maintenance	9,000.00	9,500.00	9,000.00	9,000.00	9,000.00	9,000.00
Production (Total)	$171,885.00	$131,710.00	$140,410.00	$126,310.00	$148,560.00	$143,460.00
Fixed Charges 15%	69,483.00	82,455.00	80,291.00	79,514.00	78,783.00	83,460.00
Total Cost at Bus	$241,368.00	$214,165.00	$220,701.00	$205,824.00	$227,343.00	$226,920.00
Cost per kw-hr.						
Production	$0.0262	$0.0201	$0.0214	$0.0193	$0.0226	$0.0218
Fixed Charges	0.0106	0.0125	0.0122	0.0121	0.0120	0.0127
Total	$0.0368	$0.0326	$0.0336	$0.0314	$0.0346	$0.0345

Load Factor 75%

Fuel	$183,925.00	$132,475.00	$141,750.00	$125,300.00	$157,150.00	$145,250.00
Labor	12,260.00	12,660.00	12,660.00	12,660.00	12,660.00	12,660.00
Lubricants	350.00	600.00	600.00	600.00	600.00	600.00
Supplies	3,700.00	4,200.00	4,300.00	4,200.00	4,400.00	4,200.00
Operation (Total)	$200,235.00	$149,935.00	$159,310.00	$142,760.00	$174,810.00	$162,710.00
Maintenance	10,000.00	10,500.00	10,500.00	10,500.00	10,000.00	10,000.00
Production (Total)	$210,235.00	$160,435.00	$169,810.00	$153,260.00	$184,810.00	$172,710.00
Fixed Charges 15%	69,483.00	82,455.00	80,291.00	79,514.00	78,783.00	83,460.00
Total Cost at Bus	$279,718.00	$242,890.00	$250,101.00	$232,774.00	$263,593.00	$256,170.00
Cost per kw-hr.						
Production	$0.02135	$0.01623	$0.01725	$0.01554	$0.01869	$0.01752
Fixed Charges	0.00705	0.00837	0.00815	0.00808	0.00800	0.00846
Total	$0.0284	$0.0246	$0.0254	$0.0236	$0.0267	$0.0260

were current in the vicinity of Philadelphia in February, 1923. To take care of continuity of service all the plants have been laid out with four 500-kw. generating units and ample boiler capacity. In this way there will be sufficient capacity provided for carrying peak loads with one generating unit and one boiler out of service. Electric current is to be generated at 2300 v., 3-phase and 60 cycles. The operating costs have been assumed on the basis of three load factors; namely, 25, 50 and 75 per cent.

By referring to the table on the opposite page it will be noted that the comparison of costs is based primarily upon the type of main generating unit used, these are, steam turbines, uniflow engines, simple and compound four-valve engines and simple and compound Corliss engines. Steam pressures at the throttle have been assumed as follows: turbines 200 lb. per sq. in. gage, uniflow and four-valve engines 175 lb. per sq. in. gage and Corliss engines 150 lb. per sq. in. gage. Atmospheric back pressure is assumed in all cases.

All boiler plants have been laid out to operate at maximum efficiency at 175 per cent of normal rating. All boiler plants are stoker fired and are capable of operating at 250 per cent of rating for a period of not less than 2 hr. Boiler efficiencies have been assumed as follows: 65 per cent at a load factor of 25 per cent, 70 per cent at a load factor of 50 per cent and 73 per cent at a load factor of 75 per cent. All coal is assumed to contain 13,500 B.t.u. and to cost $7 per T. delivered at the plant.

All figures covering maintenance are based on data from similar plants which are in actual operation. Annual fixed charges are assumed at 15 per cent for all plants. This latter point may readily lead to some discussion, however, it serves to place all units on a comparable basis. The curves given in Fig. 1, 2 and 3 show the average economy guarantees made for each of the various prime movers. Each curve represents the average of several manufacturers' guarantees.

Labor cost for operation is based on the following figures:

Class of Employe	Turbine and steam engine plants Load factor 25%	Load factor 50% and over	Salary per Month
Chief engineer	1	1	$225
Watch engineer	2	2	$150
Assistant engineer	0	0	$125
Firemen	3	3	$125
Laborers	1	2	$90

Study of the table which shows investment costs indicates that the cost per rated kilowatt is lowest for the steam turbine plant, this being $308.81 per kw. at the peak load of 1500 kw. The highest investment costs are for the compound Corliss plant and the second highest cost is that of the uniflow engine plant. It is interesting to note that the cost for the turbine plant is considerably lower than any of the other plants, the costs of which are grouped relatively close together.

Operating costs at 25 per cent load factor are lowest for the compound four-valve engine plant, the uniflow engine plant being only slightly higher. In contrast to the investment costs it will be noticed that the turbine operating costs are shown to be the highest.

At the load factors of 50 and 75 per cent the compound four-valve engine plant is still the lowest in cost per kilowatt with the uniflow engine plant still in second place. The turbine operating costs are again the highest. The operating costs for all units at 75 per cent load factor are slightly less than half of what they are at 25 per cent load factor.

These cost data were taken from the report of the prime movers committee of the N. E. L. A.

Boiler Feed System in Sugar Refinery---II

FRESH WATER MAKE-UP, STORAGE SYSTEMS, FILTERS, SOFTENERS, AND FEED WATER TESTING. BY CLAUDE C. BROWN

BETWEEN two million and three million gallons of fresh water are used at this refinery every 24 hr. This water is hauled to the refinery from the Sacramento river by barges, the hauling distance varying from one mile in the rainy season to 40 mi. in the middle of summer. The floating equipment for transporting this water consists of two tugs of 300 and 500 hp. respectively and three wood barges having capacities of 450,000, 500,000 and 600,000 gal.

These barges are hauled up the river to a point where the water contains the minimum allowable percentage of salt water from the bay, their sea-cocks opened, allowing them to fill through the bottom and hauled back to the plant. During the periods of long haul this floating equipment is operated continuously during a six-day week.

Arriving at the refinery a connection is made between the refinery water system and the pumping equipment on the barge through two 10-in. flexible rope wound rubber hoses. One of the barges, the 600,000-gal. boat, has installed upon it, two 2800-g.p.m., 10-in. motor-driven centrifugal pumps to which power is supplied at the dock for pumping out. The 500,000-gal. barge is similarly equipped with two 12-in. pumps, one of which has a rated capacity of 5000 g.p.m. and the other 4200 g.p.m. The third barge is equipped with one 12-in. 4200-g.p.m. pump and one 8-in., 1600-g.p.m. pump.

Sacramento River water contains a large quantity of mud silt and other impurities such as sewage refuse, especially during the rainy season of the year, and in order to free it of this suspended matter there are added to the water upon its arrival at the refinery, varying amounts of sulphate of aluminum, which acts as a coagulant and forces the mud, silt and other solid impurities to settle out of the water as soon as it comes to rest in the storage basins and tanks.

STORAGE TANKS AND CISTERNS

As the barges are brought to the refinery they are pumped out by means of the pumps on the barges, the water being directed to a steel yard storage tank with a capacity of 1,590,000 gal. From this tank, the water is either pumped by means of a 500 g.p.m. geared triplex plunger pump, to two steel storage tanks, each having a capacity of 2,290,000 gal. located on a hill about a quarter

of a mile from the main plant or allowed to flow by gravity to a cistern underneath the refinery which has a capacity of approximately 1,000,000 gal. Having thus ample storage capacity for water, the latter gets an opportunity to remain stationary for a period of time, thereby allowing the mud, silt, etc., to settle out. The yard storage tank is fitted with a floating discharge inside the tank so that the water is always drawn off the top rather than the bottom, thus further insuring delivery of the clearest water.

Water Filters

From the concrete cistern underneath the refinery, the water is picked up by two 7-in. 1300 g.p.m. motor-driven centrifugal pumps and forced through eight California Jewel Sand Filters. Five of these filters are of the vertical type, being 8 ft. in diameter and 8 ft. high and having a filtering surface area of 50 sq. ft. and a capacity of 100 gal. of water per minute. The remaining three filters are of the horizontal type, 8 ft. in diameter and 20 ft. long. These latter filters have a filtering surface area of 160 sq. ft. and a filtering capacity of 320 g.p.m.

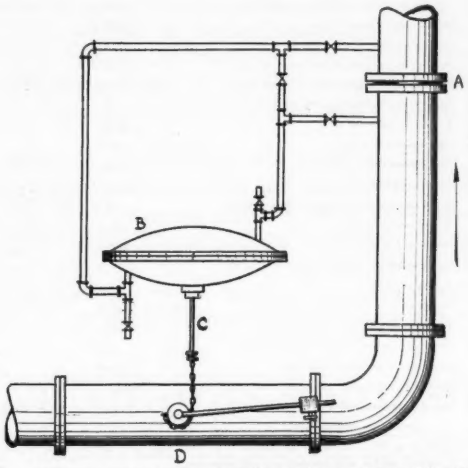


FIG. 1. MECHANISM FOR REGULATING WATER TO FILTERS

The operation of the filters consists of the water being pumped into the top of the filter tanks, spread over the upper surface of the filter sand by a diffuser plate, the water percolating down through the sand and gravel, being collected from among the lower or larger layer of gravel through the horizontally slotted nozzles on the manifold in the bottom of the tank and thereby delivered to the outlet header.

This operation removes the greater part of the suspended silt and refuse from the water and it is then considered sufficiently purified for the purpose of refining sugar. After the filters have been in operation for a period of 8 hr., the sand becomes pretty well impregnated with mud. It is then washed for a period of 3 min. by reversing the direction of the water through the shell; in other words, the water is admitted to the filter from the bottom outlet, passing up through the horizontally slotted nozzles, up through the gravel and finally through the sand bed and out the inlet of the filter where it is bypassed to the sewer.

In order to kill the growth of moss or "algae" in the filters, during the summer months of the year when it is prevalent, varying amounts of copper sulphate solution are added to the water as it is pumped out of the barges. This treatment has been found effectually to prevent the growth of the fungus.

All of the eight sand filters are connected in multiple, that is, there is installed one inlet header (10-in. pipe) into which the pumps deliver and to which is connected the 6-in. inlet to each filter, and similarly a 10-in. discharge header to which each filter delivers its water, with also, of course, the necessary bypass connections, overboard wash line connections, etc. Due to the fact that these filters are so connected, and also that the pump feed to the inlet header and the discharge line from the outlet header are at a point extremely near the center of these headers, it will be readily appreciated that the water will tend to take the shortest course through the system and

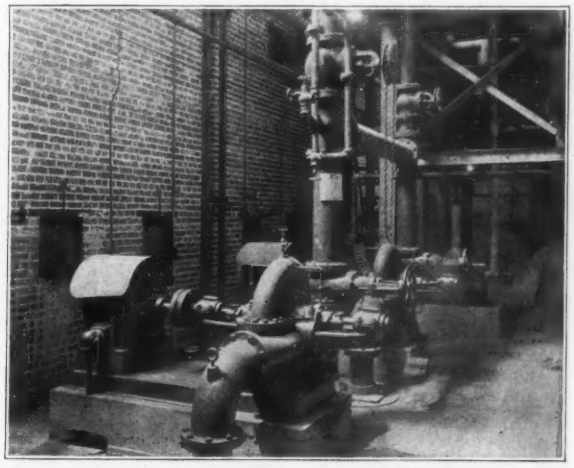


FIG. 2. THE SERVICE PUMPS ARE MOTOR DRIVEN

that most of it will tend to pass through the filters that are located near the inlet and discharge lines. Experience has shown that this very thing takes place, and that those filters located near the center of the battery carry by far the greatest portion of the load and the filters near the ends of the battery carry practically none. In order to overcome this difficulty and to equalize the load on all of the filters an automatic regulating apparatus was installed on the outlet of each filter, by means of which the quantity of water passing through each filter or rather the rate of filtration of the filter, is limited to the maximum capacity of the filter. Figure 1 illustrates diagrammatically the essential parts of one of these automatic water regulators, or what might be termed, "mechanical limit switches."

In the outlet line from the filter, at A, is installed an orifice plate through which all of the water from the filter in question must pass. On either side of this orifice plate are installed the connections, "pressure connections," they are called, which carry the respective pressures from the leading side of the orifice plate to the top of the diaphragm B, and from the trailing side of the orifice plate to the under side of the diaphragm B. The diaphragm B is so constructed that its upward or downward motion actuates a corresponding upward or downward motion in the stem C. The stem C is attached to a chain which operates butterfly valve D. Attached to the sprocket on which the chain works and which is keyed to the shaft

of the butterfly valve, are an arm and weight which tend to throw the butterfly valve open.

Operation of the arrangement is simple, positive and entirely automatic. With a small quantity of water passing through the line, the pressures on either side of the orifice plate A are approximately the same, hence stem C is at its lower limit position, which allows the weight arm to swing the butterfly valve D wide open. As the rate of filtration of the filter increases and a greater quantity of water is passing through the outlet line per minute, the differential in pressure between the inlet and outlet sides of the orifice plate increases. This action decreases the pressure on the top of the diaphragm, thereby allowing the constant line pressure on the under side of the diaphragm to force the stem C upward, closing in the butterfly valve

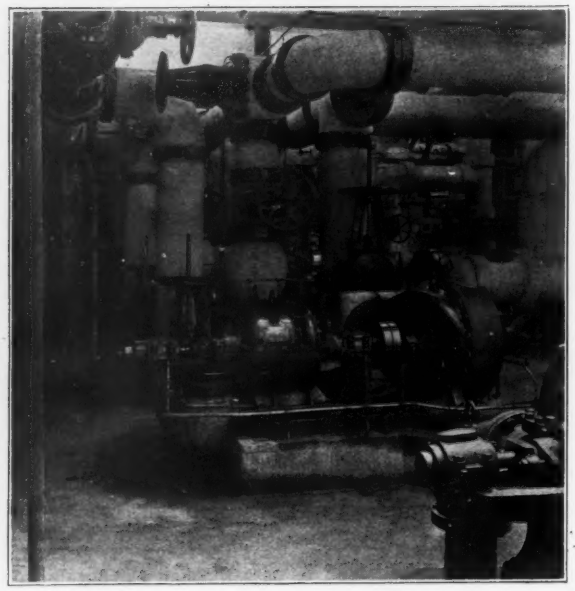


FIG. 3. VIEW OF THE BOILER FEED PUMPS

D and limiting the rate of filtration to any predetermined figure. This limiting figure is determined by the size of the orifice, and the position of the counterweight on the butterfly valve arm.

Water Softener

That portion of the filtered water that is to be used for the fresh water makeup of the boiler feed water, is passed through a Booth cold water softener. This softener has a capacity of 27,000 gal. of treated water per hr., and a storage capacity of 17,000 gal. of treated water.

In regular operation, the quantity of water passed through this softener is maintained constant; that is, the regulating valve on the inlet water line is set at a given position and kept there as long as the production of treated water is sufficient to keep the treated water cistern nearly filled. There is an advantage in keeping the flow of water through the softener constant in that the action of the softener is more satisfactory when it is run evenly. A Venturi meter is installed in the line that feeds the softener so that a record is kept of the amount and rate of the flow to the tank.

Chemicals used in connection with this treatment are lime and soda ash. In treating the average river water, 0.6 lb. of 90 per cent lime and 0.3 lb. of 99 per cent soda ash are dissolved in the chemical mixing tank in a tank full of water, with the aid of a jet of exhaust steam.

The large wood softener tank is divided into two parts by a vertical wood partition which extends from the top of the tank to within about four feet from the bottom. This center partition is of treble thickness to prevent the flow of the water from one side to the other, the course of the water being in at the top of one side, down under the partition and up the other. The side into which the makeup water and the lime and soda mixture enter contains two revolving stirrers which thoroughly mix the treatment and the makeup water as they pass down the inlet side of the large tank. The velocity of the water through the tank is very low, being an average of 0.15 ft. per min., the total length of travel being about 70 ft. down one side,

BOILER ROOM PERFORMANCE FOR 24 HOURS ENDING 8 am 7/28 1922

A	Oil used	Pounds per hour	20795	See "Oil Fuel" Page 34
B	Water to boilers	" " "	320916	
C	Water blown off	" " "	8000	
D	Water evaporated	" " "	312916	D = B−C
E	Temperature of feed water entering boilers	Deg. Fahr.	286	
F	Total heat per pound of steam at ..... pounds Gage Press.	B. t. u.	1195	See "Steam" Page 123
G	Total heat per pound of feed water entering boilers	"	204.2	See "Steam" Page 120
H	Net heat added per pound of steam	"	990.8	H = F−G
J	Total heat per pound of water blown off	"	338.2	See "Steam" Page 123
K	Net heat added per pound of water blown off	"	134.0	K = J−G
L	Total equivalent evaporation from and at 212 °F.	Lbs.	321055	$L=\frac{D\times H+C\times K}{970.4}$
M	Equivalent evaporation from and at 212 °F. per lb of fuel oil	"	15.3	$M=\frac{L}{A}$
N	B. t. u. per pound of fuel oil		18700	
P	Steam consumed by burners	Lbs. per hour	3897	
Q	Gross efficiency (boilers only)		80.0	$Q=\frac{D\times H+C\times K}{A\times N}\times 100$
R	Factor of evaporation		1.021	R = H−970.4
S	Net efficiency (boilers only, deducting steam to burners)		79.0	$S=\frac{D\times H+C\times K-F\times H}{A\times N}\times 100$
T	% steam used by burners		1.23	$Y=\frac{F\times H}{D\times H+C\times K}\times 100$
U	Total B. H. P. developed		9305	$U=\frac{L}{34.5}$
V	Number of boilers in service		11	
W	% rating of boilers		140	$W=\frac{U}{300\times V}\times 100$
X	Temperature of feed water leaving economizers	Deg. Fahr.	236	
Y	Temperature of feed water entering economizers	"	182	
Z_1	Rise in temperature of feed water in economizers	"	54	
X_1	Temperature of flue gases leaving boilers	"	529	
Z_2	Temperature of flue gases leaving economizers	"	363	
X_1	Drop in temperature of flue gases through economizers	"	166	$X_1=X-Y$
Z_2	CO_2 (Averaged from recording charts)	%	12.2	$Z_1=Z_2-Z_1$

NOTES—In order to be able to compare the performances of the boilers from day to day, five barrels of oil should be deducted from the total amount of oil used during a day when a cold boiler has been fired up and put on the line. No deduction should be made when starting up a cold economizer.
All values given above are the average for the 24-hour period.
For purposes of this log, assume dry steam leaving boilers.

Total amount of water fed to boilers per week.....
Amount of purified water fed to boilers per week.....
% purified water to total water fed to boilers per week.....

Claude C Brown
Power Engineer

FIG. 4. THE BOILER ROOM LOG

across the bottom and up the other side. At the top of the outlet side of the tank is placed an excelsior filter which covers the entire area of that half of the tank, and is four feet deep. The purpose of this filter is the removal of the suspended precipitate resulting from the softener action and it consists of some 1500 lb. of packed excelsior. This excelsior is of the first grade and lasts about 90 days after which it becomes heavily coated with Calcium Carbonate and has to be replaced. On the bottom of the tank is installed a series of sludge headers consisting of vitrified pipe in the top of which are small holes spaced at intervals of 6 in. along the headers. These headers terminate in quick opening valves outside the tank by means of which the sludge in the bottom of the tank is removed once during each 8-hr. shift. This sludging of the tank is an extremely important factor in the operation of the softener and should be done with the utmost care. The sludge valves must be opened slowly at first and gradually opened wide until the sludge water shows clear.

From the softener the outlet line takes the purified water from a point about 18 in. above the top of the excelsior filter, drops down the side of the tank and discharges into the top of a number of closed gravity sand filters. From these filters it passes down into the treated water cistern underneath the boiler house.

This treated water cistern is a concrete storage basin which extends the entire length of the boiler house and has a capacity of approximately 160,000 gal. From this cistern the treated water is picked up by two 1000-g.p.m. Krogh centrifugal service pumps shown in Fig. 3 and pumped to the header over the tops of the two feed water heaters. The quantity and rate of the flow of makeup treated water into the feed water heaters is regulated by float valves which keep the water level in the feed water heaters at 4 ft. from the bottom of the heater tanks. In addition to this 6-in. line from the service pumps, there is a 4-in. line through which water may be delivered to the feed water heaters from the treated-water cistern by a steam-driven emergency pump which is automatically put into operation by a pressure regulating governor in the case that the power should go off and the service pumps fail. The pressure in the discharge line of this pump is regulated by floats in the feed-water heater tanks which open the valves in the 4-in. line when the water level in the feed water tanks falls below 2 ft. The purpose of this emergency installation is the prevention of the condition of the feed-water tanks becoming dry, in which case the turbine feed water pumps would run away.

Feed-water heaters are of the Cochrane design, open type, fitted with cast-iron water seal overflow, installed on a special reinforced concrete platform about 17 ft. above the boiler room floor. The capacity of each heater is 250,000 lb. of water per hr. with a water storage capacity of 583 cu. ft. between safe water levels. The heater shells are capable of 10 lb. back pressure from the exhaust steam and water and are thoroughly insulated with asbestos. A 10-in. vapor vent vents the vapor to the roof through a Cochrane multiport relief valve set at 15 lb.

From the feed-water heaters the feed water drops to two 1000-g.p.m. Byron-Jackson steam turbine driven 6-in. multi-stage centrifugal feed pumps. These pumps operate against a total head of 462 ft. and run at 1800 r.p.m. The turbines are of the Curtis type, manufactured by the General Electric Co., single-stage, 175-hp., 1800-r.p.m. equipped with automatic and emergency governors. Figure 4 shows one of these feed-water pumps in operation. An emergency piping connection is provided by means of which raw water can be supplied to these pumps in case of failure of the treated water system.

From the turbine-driven boiler feed pumps, the feed water is pumped through a 10-in. Venturi water meter having a capacity of from 55,600 to 722,000 lb. of water per hour, at a temperature of 150 deg. F.

From the Venturi meter the feed water passes to five Green fuel economizers each consisting of 32 sections of 10 tubes, the latter being of cast iron, 4⅝ in. external diameter by 12 ft. long. The capacity of each economizer is 19,840 lb. of water and each has a heating surface of 4080 sq. ft.

Water from the economizers is fed to each boiler from the boiler headers and the quantity of water fed to each boiler is controlled by a Copes boiler feed water regulator. Figure 4 shows the boiler room log for 24 hr. and gives an idea of the feed water conditions obtaining under average operating conditions at this plant.

Tests are made of the feed water at half hour intervals for the purpose of determining the sugar content and the other solids in solution. Tests are also made of the water in the boilers at 8-hr. intervals for the purpose of determining the density of the water in the boilers, the latter in turn determining the quantity and frequency of blowdown.

Evaporators Furnish Distilled Make-Up Water

Modern Boiler Practice Demands Pure Feed Water; Evaporators Meeting Needs in Large Condensing Plants

WITH the increasing use of high pressure steam and the working of boilers at higher ratings has come the greater necessity for pure feed water that will not form scale in the boiler nor corrode the boiler metal. The answer to this problem in many plants is the use of evaporators to furnish distilled water for make-up purposes.

Evaporators first used for this purpose were designed originally for industrial purposes or for distilling sea water but of recent years as the need for evaporating systems has made itself manifest in the power plant designs have been modified to suit the particular conditions that surround the individual power plant.

Essential Features of Evaporators

In general the evaporator consists of a water and steam tight shell into which the raw water is fed. The heating element is a steam coil which may be supplied with live steam from the boiler either direct or at reduced pressure but the usual arrangement is to boil the water with exhaust steam from the auxiliaries or with steam bled from one of the lower stages of the main turbine.

Some evaporators maintain the level of the water in the evaporator above the steam coils while others, called the film type, keep the water in circulation by means of a pump, causing it to flow over the coils in a thin sheet.

Depending upon operating conditions in the plant, a single evaporator may be used or two or more evaporators used in series, the arrangements being called single, double or multiple effect. In the single effect arrangement the vapor driven off from the water is led directly to a condenser, the condensate being delivered to the hot well. This condenser may be that serving the main unit but is usually a separate condenser using the condensate from the main unit to condense the vapor from the evaporator.

Double and multiple effect arrangements differ from the single effect in that the vapor from the first effect is condensed in the second effect and in condensing evaporates the water in the second effect, vapor from the second effect goes to the third effect and so forth to the last effect the vapor from which goes to the condenser. All condensate goes to the hot well.

As water evaporates, that remaining becomes saturated with impurities so it is necessary to blow down the evaporator either continuously or intermittently in order to maintain efficient evaporation. In the case of fresh water the blow-down amounts to 4 or 5 per cent of the amount

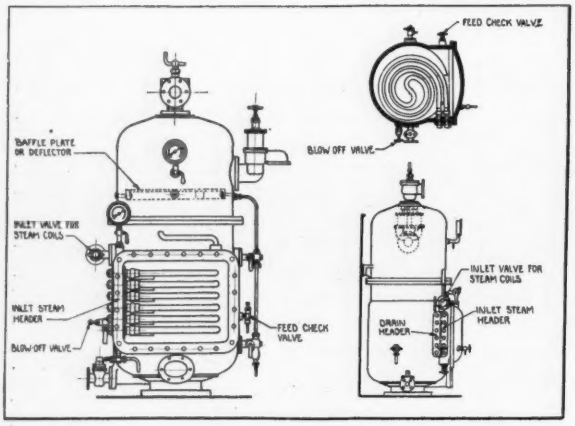


FIG. 1. HEATING ELEMENT OF BETHLEHEM-WEIR EVAPORATOR IS MADE UP OF HELICAL COILS PLACED HORIZONTALLY

evaporated while for sea water the blow-down necessary runs as high as 35 per cent.

In Fig. 1 are shown the essential features of the Bethlehem-Weir evaporator, which is provided with an automatic feed regulator and blow-down ejector designed to secure the advantage of continuous blow-down and uniform density. The ejector consists of a water jet so arranged as to draw water from the evaporator and discharge the mixture to waste. Feed to the evaporator is controlled by means of a float regulator which maintains a constant water level at any rate of output up to the maximum for which the evaporator is designed.

In order to prevent water from being carried over with the vapor a deflector is provided separating the tube space from the steam space so designed as to throw the water back into the water space.

Heating tubes are of copper and arranged in elements, each element consisting of a single tube coil with special hollow couplings on inlet and outlet ends in the same plane. These hollow couplings pass through a steam header cast on the back or side of the evaporator and are secured in place from the outside by means of a cap nut on the end of each coupling.

Outlet openings from the tubes are of smaller diameter than the inlets with the exception of that in the lowest drain tube, which is the same area throughout, and through which any steam passing through the evaporator along with the water of condensation and drained to the hotwell.

In the Reilly evaporator, one type of which is illustrated in Fig. 2, the heating coils are attached to manifolds secured to the door and assembled with the door, all removable from the shell. The coils are of seamless brass tubing, the ends being equipped with detachable flanged joints making a metal to metal cone-faced bolted joint. Copper or brass baffles are so arranged as to increase circulation and minimize priming. Zinc plates are used in steel shell evaporators to protect the steel from galvanic action and are conveniently arranged for replacement. Due to the expansion and contraction movement of the coil with changes in temperature, they are self-scaling and thus maintain an efficient heating surface.

Schutte & Koerting Co. employs a somewhat different arrangement in that the water is brought up in tempera-

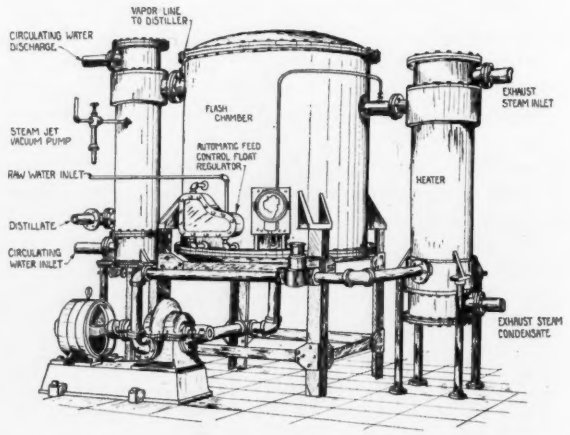


FIG. 3. HEATED WATER IS FLASHED INTO VAPOR BY REDUCING THE PRESSURE IN THE SCHUTTE & KOERTING EVAPORATING SYSTEM

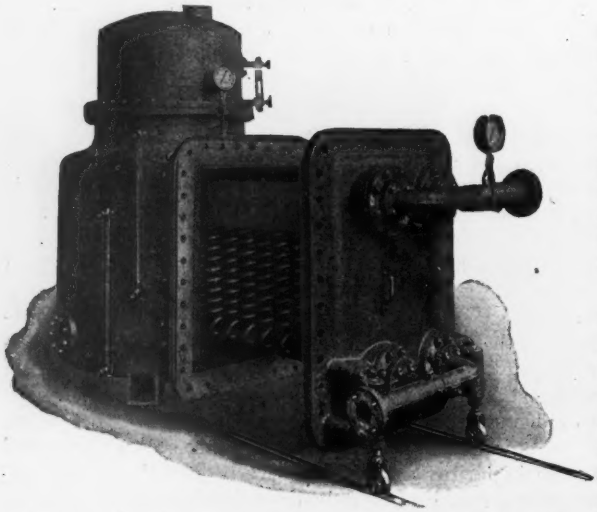


FIG. 2. THE ENTIRE HEATING ELEMENT IS REMOVABLE FROM THE REILLY EVAPORATOR

ture nearly to the boiling point in a separate heater and then flashed into steam by reducing the pressure in the evaporator proper. The temperature to which the water is heated in the tubular heater is below both the boiling point at atmospheric pressure and the temperature at which impurities in the water can be deposited as scale. The temperature is, however, higher than the temperature corresponding to the vacuum maintained in the flash chamber. Upon entering the flash chamber, the water flashes into vapor which passes to the condenser.

In operation, the cold raw water is forced by a circulating pump through the make-up water piping and the automatic feed control valve and then discharged into the heater. In passing from the heater into the flash chamber, which is maintained at a vacuum of about 16 in., the water at about 199 deg. F. is flashed into steam. The flow of water to the heater is regulated by float controlled valve which maintains a constant level of water in the flash chamber.

Within the flash chamber the structure is so arranged as to subdivide the incoming water into a multitude of thin

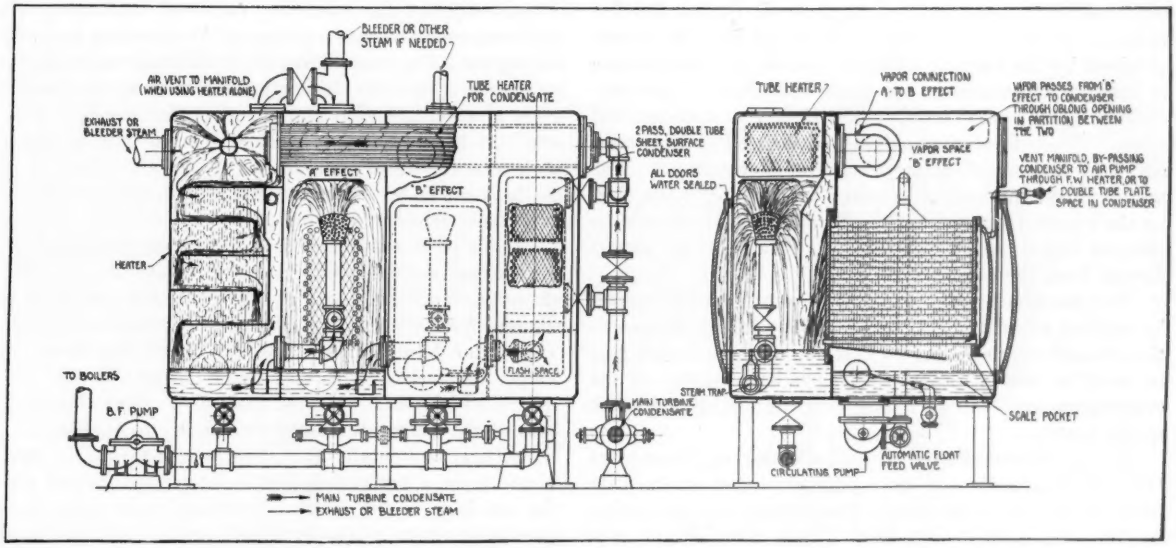

BLEEDER OR OTHER STEAM IF NEEDED
AIR VENT TO MANIFOLD (WHEN USING HEATER ALONE)
TUBE HEATER FOR CONDENSATE
EXHAUST OR BLEEDER STEAM
'A' EFFECT
'B' EFFECT
HEATER
TO BOILERS
B.F. PUMP
FLASH SPACE
2 PASS, DOUBLE TUBE SHEET, SURFACE CONDENSER
ALL DOORS WATER SEALED
MAIN TURBINE CONDENSATE
STEAM TRAP
TUBE HEATER
VAPOR CONNECTION A TO B EFFECT
VAPOR SPACE 'B' EFFECT
VAPOR PASSES FROM 'B' EFFECT TO CONDENSER THROUGH OBLONG OPENING IN PARTITION BETWEEN THE TWO
VENT MANIFOLD, BY-PASSING CONDENSER TO AIR PUMP THROUGH F.W. HEATER, OR TO DOUBLE TUBE PLATE SPACE IN CONDENSER
SCALE POCKET
CIRCULATING PUMP
AUTOMATIC FLOAT FEED VALVE
MAIN TURBINE CONDENSATE
EXHAUST OR BLEEDER STEAM

FIG. 4. MULTI-CELL CONSTRUCTION IS A FEATURE OF THE LILLIE EVAPORATOR

films. The water not evaporated by the flashing of the water at 199 deg. into vapor at 176 deg. is withdrawn from the flash chamber, mixed with the incoming evaporator make-up water and recirculated. Part of this liquid is continuously blown off on the discharge side of the circulating pump, thus preventing precipitation of scale forming material. The steam condensate from the heater as well as the condensed vapor is used for boiler feed make-up.

Multiple effect 1922 model Lillie evaporators are constructed in two forms, one in which the effects are individual and are connected together to form multiple effects by vapor, liquor and condensate piping. The other is the multicell construction in which the individual effects are contained in an enclosing shell each cell serving as an effect with the intercell vapor and other passages formed mostly within the shell.

Figure 4 illustrates the multicell construction which is divided into four divisions, one for the plant heater, two for the effects of the double effect and one for the surface

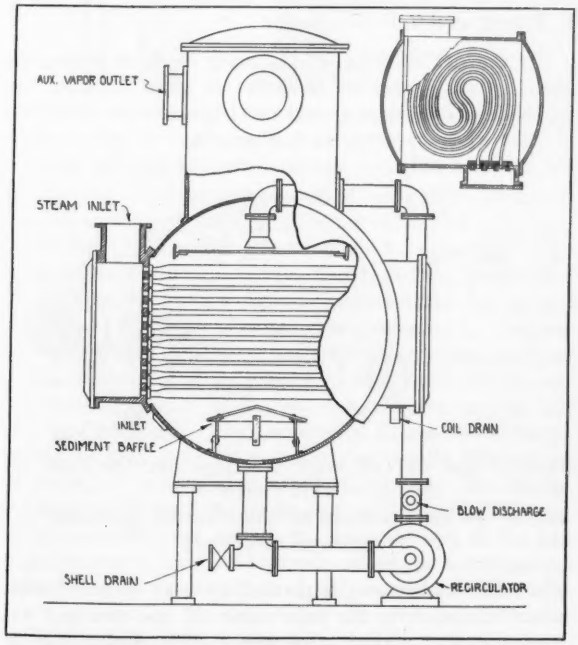


FIG. 5. FILM EVAPORATION AND CONTINUOUS BLOWDOWN ARE EMPLOYED IN WHEELER CONDENSER & ENGINEERING CO. EVAPORATORS

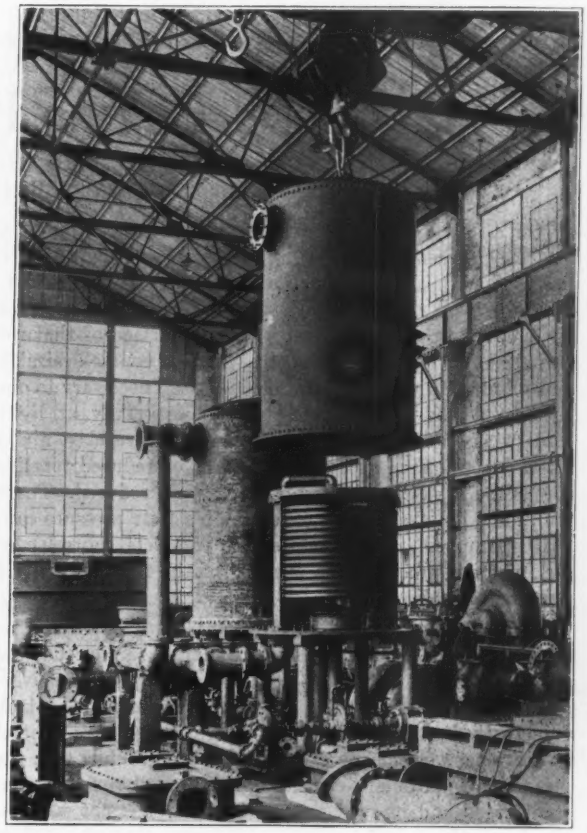


FIG. 6. SHOP VIEW OF WHEELER VERTICAL TYPE, DOUBLE EFFECT EVAPORATORS

condenser of the evaporators. In this construction the distillation of the raw water is effected mainly by vapors obtained by the flashing down of heated main condensate to lower temperatures in the steam chambers of the evaporator, assisted when needed by exhaust or turbine bled steam. Flash-down is employed to deaerate the feed water and may be limited to the hot effect if preferred. The main turbine condensate is heated for flashing down, first by the vapors from the cool evaporator and afterwards by exhaust steam or by turbine bled steam or by vapors flashed from the condensate.

The non-condensable gases are taken from the system by venting at each effect. So long as nothing is open to the atmosphere, degassing by one, two or three flashes may be practiced even if no evaporating is being done. If the evaporators are open to atmosphere, degassing is limited to the heater.

In the construction of this evaporator equipment the tubes of the condensate heater are expanded in the tube plate at the entering end for the condensate and are packed in the tube plate exit end. The intermediate tube plates are of composition and through these each tube passes with a sliding fit. After opening a swinging door with which the heater is fitted, all the internal parts may be removed and access had to the heater end tube plate of the tube heater.

Evaporators made by the Wheeler Condenser & Engineering Co. are of the film type and may be of either the horizontal or vertical shell construction. In the horizontal type the heating tubes employed may be of either the return bend type or what is termed the ellipticoil, the vertical type, however, is always provided with ellipticoil heating surface. These coils are arranged in units arranged horizontally one above another, each coil unit being independently mounted and resting on a supporting bar. The tubing used for these coils is of elliptical cross section, which, together with the method of shaping and bending gives a weaving action and distortion of the coil with a small temperature and pressure difference thus preventing the accumulation of scale deposits. The coils are attached to the headers by detachable couplings, making each coil unit easily removed and replaced.

Water to be evaporated is mechanically circulated over the heating surface producing thin, rapidly moving films of water on the coils and giving a scouring action as the shower of water continually washes down the bank of coils. The water level is maintained by admitting fresh feed water, the level being carried below the bottom coil. It is controlled by a float operated feed valve. The water in the base of the evaporator flows continually to suction of the centrifugal recirculator and is discharged through a special nozzle upon a perforated distributing plate located above the coil bank. The excess circulating water drops to the base again where it is recirculated together with the incoming feed water. A branch pipe connected to the discharge from the recirculator serves as a blowoff connection and by properly setting the blowoff valve a desirable percentage of continuous blowdown can be obtained.

Protection of the recirculator against particles of scale is provided for by means of a conical sediment baffle, consisting of a collar, with a top shield, arranged so that any scale particles from the coils above will fall into the evaporator base and not flow into the recirculator suction.

In order to insure high purity of the distilled vapors leaving the evaporator, a separator is located in the vapor dome.

Diesel Engine Fuel Valves---III*

DESCRIBING THE CONSTRUCTION AND ACTION OF COMMERCIAL TYPES OF FUEL VALVES. BY H. F. BIRNIE AND R. C. BAUMANN

SOMETIMES THE point is raised as to the value of a fuel needle lift control, since some engines are equipped with a control mechanism while others are not. On light loads or at reduced speeds the quantity of blast air required to inject the fuel is only a fraction of that required at full load or high speed. It is of course desirable that no more injection air can be used than necessary to obtain rapid and complete combustion, especially at light loads when the chilling effect of the excessive blast air is most objectionable, hence at light loads or reduced rotative speeds the injection air pressure is always reduced. There are limits, however, below which the blast air pressure cannot be dropped, therefore to secure complete control over the injection processes the opening of the fuel valve itself must be variable.

It is most common to find lift controls fitted on marine engines since it is most essential in marine service that the engines function as well at low speeds as when maneuvering. Most stationary engine builders do not fit a control, principally because of its cost. The omission of a control on stationary engines is excusable on the grounds that the majority of stationary engines operate at all times at constant speed and in such service the control is not a necessity but rather a refinement.

If the lift of the needle is made small it is desirable that the lead should not be decreased when doing so; that is, the injection valve should not begin to open later than it does when opening its full amount. Figure 1 shows the original and most simple device for varying the valve

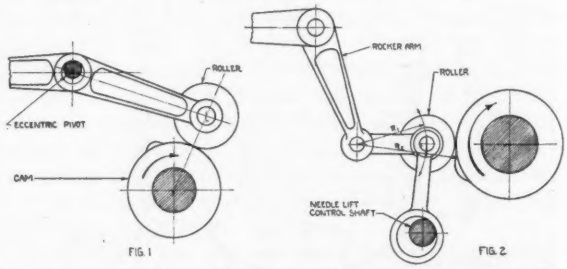


FIG. 1. ONE OF THE FIRST METHODS USED TO VARY THE VALVE LIFT

FIG. 2. IN THIS SCHEME OF CONTROLLING THE LIFT, LEAD REMAINS CONSTANT

lift. The rocker arm is pivoted upon an eccentric which when rotated lifts the cam roller off the cam and thus increased the running clearance. This design has two defects: First, the increased roller clearance results in knocking; second, as the needle lift decreases the lead also decreases.

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In order to overcome this last defect, Sulzer Bros. for a time used the design of Fig. 2. The cam roller was caused to swing about the end of the rocker arm on an arc of radius R_1 when it was desired to change the amount of valve opening. Swinging the roller downward decreased the lift. The leading face of the cam was concave, being a sector of an arc with radius R_2 swung from the same center as R_1. It will be appreciated that in this case decreased needle lift was also obtained by increasing the clearance between cam and roller but the lead remained constant irrespective of the position of the roller.

Two types of control which represent current practice are found on Fulton Diesels (Fig. 3) and on Nelseco and M. A. N. engines. In these designs the clearance and the

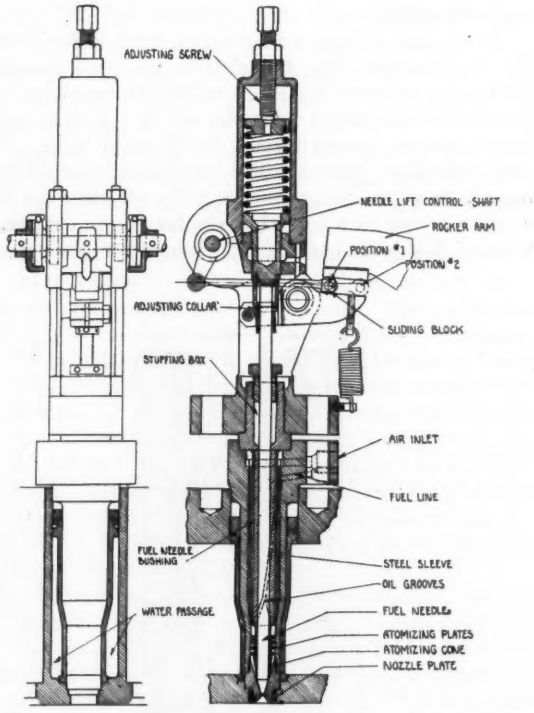


FIG. 3. FULTON VALVE SHOWING METHOD OF OBTAINING THE LIFT CONTROL

lead are the same for any degree of valve lift. Figure 4 is a section through the fuel injection valve of the Nelseco Engine built by the New London Ship & Engine Co. The needle lift control mechanism is similar to that used on the last German submarine engines manufactured by the famous M. A. N. firm. The bell crank actuated by the fuel cam on the cam shaft does not act directly upon the fuel needle. The upward movement of this crank end serves only to compress the larger, outer coil spring and to lift it off the fuel needle. Thus relieved of all downward forces tending to hold it to its seat, the fuel needle lifts under the action of the smaller internal coil spring. The needle continues to lift until the upper stop collar, screwed fast to the valve needle stem, strikes the lower surface of the lift regulating screw, held in the upper end of the valve casing. The amount of needle lift is therefore regulated entirely by the position of the regulating screw and not by the amplitude of the rocker movement, which is always constant. The regulating screw is easily and conveniently adjusted while the engine is in operation, to suit different

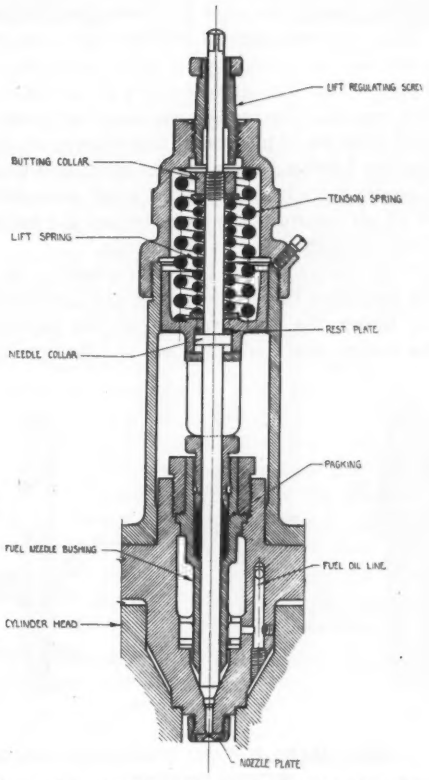


FIG. 4. FUEL VALVES USED ON NELSECO AND M. A. N. ENGINES

speeds or loads. As the valve rocker returns to its original position the needle again comes under the control of the larger spring, which overcomes the smaller spring and forces the needle to its seat.

Figure 5 is a section through the fuel and starting valves of the two-cycle engines made by Sulzer Bros. of Wintertur, Switzerland. A similar design is used by the American licensee, The Busch-Sulzer Bros. Diesel Engine Co. of St. Louis, in their type "C" two-cycle engines. A

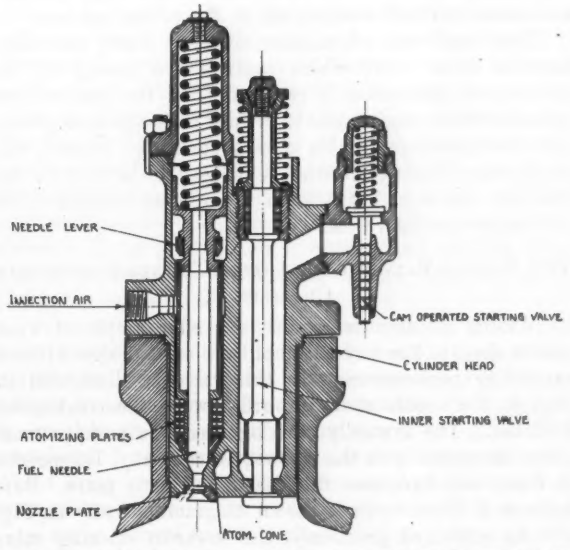


FIG. 5. SINGLE CASTING FORMS CAGE FOR BOTH FUEL AND STARTING VALVES IN BUSCH-SULZER SCHEME

single casting forms the cage for both fuel and starting valves. This common cage is separate from the cylinder head proper and is cooled by its own individual cooling water supply. The distinctive feature of the fuel valve is its packing system. The needle itself does not pass through packing, its freedom of movement therefore is not impaired by stuffing-box friction. Between the main fuel rocker and the fuel needle there is interposed a small secondary rocking shaft which transmits the movement of the main rocker arm through a stuffing-box to the needle.

It will be observed that the entire mechanism of the fuel valve including the needle spring and the small rocker shaft are under the full pressure of the injection air. Since the rocker shaft is subjected to injection air pressure on its inner end and to only atmospheric pressure on its outer end, it operates under a considerable thrust pressure tending to force it endwise out of its bushings. A thrust washer is provided to take this pressure.

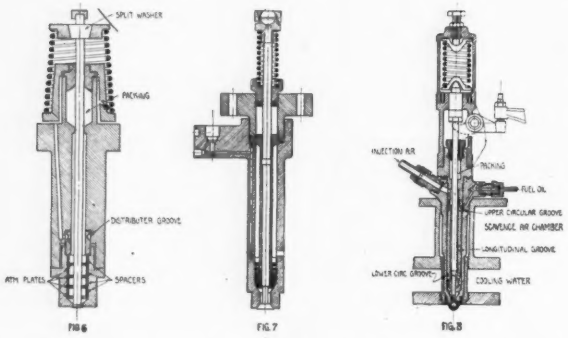


FIG. 6. NEEDLE OPENS TOWARD COMBUSTION CHAMBER IN WINTON ENGINE

FIG. 7. BURMEISTER AND MAIN FUEL VALVES

FIG. 8. FUEL VALVE USED BY THE FRENCH FIRM SCHNEIDER IS SIMILAR TO THAT USED BY NORDBERG

Starting valve design is especially noteworthy. There are in reality two valves, an inner one which stays open during the entire period of starting until the engine is turned over to fuel and an outer one which is cam operated and timed to admit starting air at the proper moment.

Two important advantages accrue. First, the more sensitive outer valve which controls the timing of the starting air admission is removed from the heat of the cylinder which might cause it to stick in its guide bushings and thereby cause trouble during starting. Second, the compression during starting is reduced by adding to the clearance space in the cylinder the volume between inner and outer starting valves.

Two Needle Valves Which Open Toward Combustion Chamber

Winton oil engines furnish a good example of what can be done in the way of simplification of design without sacrificing performance. In this valve as illustrated in Fig. 6, the needle opens inward toward the combustion chamber. The inwardly opening needle is perhaps most often associated with the Norwegian company, Burmeister & Wain, who have used this design for many years. Burmeister & Wain valve is shown diagrammatically in Fig. 7. As explained previously, the inwardly opening valve combines within itself the functions of atomizer cone and nozzle plate and hence these two items are eliminated in the Winton valve. The long vertical fuel oil duct terminates in an annular distributing groove just above the atomizing plates.

From the circular distributing groove, small diagonal channels conduct the oil directly onto the plates and into the path of the injection air. The atomizer plates are held firmly in position between the detachable cage and the distributing groove piece. The plates are, therefore, utilized as the lower guide for the needle, thus eliminating one more item found in the more complicated designs, i. e., the long needle guide bushing. The Winton valve uses an exposed valve spring which is more or less common practice in marine design. This spring also serves to keep the needle packing under compression. The exposed spring is accessible and is made readily detachable by the use of split retaining collars.

Fuel valve of the French firm, "Schneider," which, like the Nordberg Mfg. Co. of Milwaukee, is a licensee of the Belgian concern "Carels Bros.," is illustrated in Fig. 8. The fuel is discharged from the supply pipe line into an upper annular groove formed in the cage body. Three long logitudinal grooves milled into the exterior surface of the needle guide bushing conduct the oil from the upper circular groove to a lower but similar groove cut into the walls of the guide bushing from whence it flows through

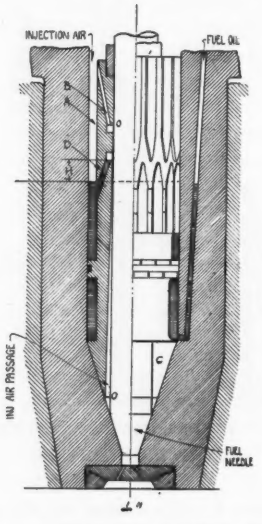


FIG. 9. OIL IS NOT INJECTED DURING FULL PERIOD OF VALVE OPENING IN McINTOSH & SEYMOUR VALVES

six small drillings toward the end of the needle and the atomizer.

It will be noticed that only air and not fuel oil can escape through the stuffing-box about the needle stem. Fuel oil cannot be relied upon as a lubricant for the needle, therefore, and other means for introducing a lubricant into the stuffing-box must be provided. This design should be compared with that of the Fulton Iron Works Co., which purposely allows the leakage of a small quantity of fuel oil past the stuffing-box in order to insure continuous lubrication of the needle. The Nordberg Mfg. Co. uses a simplified form of the Schneider valve. Conventional perforated atomizer plates are used instead of the steel balls and a standard nozzle plate is substituted for the cup like plate of Fig. 8.

Figure 9 is a section through the atomizer as used by

the McIntosh and Seymour Corp. The fit between the sleeve and the needle stem is very close at the upper end of the sleeve but directly below the upper fit the clearance between sleeve and needle increases to form an air passage of constantly increasing section. The sleeve is ground to a tight fit at its lower conical end and thus forms a reservoir for the fuel oil between itself and the valve cage.

Oil Injected During Only Part of Valve Opening Period

Oil is not injected during the full period of valve opening but only until the oil level in the lower end of passage "A" falls below the level "L." When the oil level has fallen this amount the passageways D are uncovered to the injection air which flows not only through "B" but also through "D" and consequently no more oil is injected.

Only that amount of fuel delivered by the fuel pump is injected each cycle. After each closing of the needle the same quantity of oil will always remain in the lower end of the valve.

Figure 3 shows the fuel injection valve of the Fulton Diesel engine manufactured by the Fulton Iron Works Co. This valve has a number of distinctive and interesting features.

Design of the lower end has resulted in a tapering of the entire assembly so that the valve, particularly at its lower end, has a small external diameter. The entire valve unit is surrounded by a bronze sleeve fitted permanently into the cylinder head. The use of this thin bronze sleeve, rather than cast iron partition walls, gives unusually ample passageways for the cooling water, between the injection valve and the exhaust valve and between the injection valve and the intake valve. The fuel is conducted to the atomizer plates by two grooves on a steel sleeve. Each of these grooves divides at the lower end of the sleeve into two other grooves so that the oil is distributed evenly about the atomizing plates.

Guide bushings for the needle extend almost to the seat of the needle. Fuel oil which creeps up between the needle stem and its guide bushings is conducted directly to the packing chamber. This fuel oil is sufficient automatically and continuously to lubricate the needle. This fuel valve is fitted with a variable needle lift control.

Adjusting screw for the spring tension is made hollow to permit the insertion of a small wrench which engages the needle. This aids in keeping the valve seat in good condition. The adjusting collar at the end of the secondary rocker arm permits ready adjustment of the clearance between the rocker arm and the sliding block of the lift control mechanism.

Muck-Hole Mechanics

By M. M. Brown

SOME YEARS ago, being temporarily out of employment, I was inveigled into taking a job with a gold-mining outfit to operate in a swamp in Alabama. The only part of the machinery which was new was a centrifugal (sand-sucker) pump which we took with us from New York.

When I asked the colored man, who drove the mules to haul the pump and myself to the location, what sort of a place it was, he answered: "Well, boss, you'll wish to Gawd yo' neber seen the place."

Sure enough! It was 18 mi. from the nearest village. For the last mile, there was a corduroy road, which buckled as we drove over it. Arriving at the "mine," there appeared a new scow, set in a muckhole of but little larger area than the scow itself. On the bank, was 200-hp. locomotive boiler, a 100-hp. vertical, slide-valve engine, a 20-hp. slide-valve engine, the separating machinery and pipe and fittings, all second-hand material, except the centrifugal pump.

I found that my first job was to set up the outfit and get it running before mining operations could be started. Two camps had been constructed, one for the white men and one for the colored laborers, of which there seemed to be a multitude, besides the lookers-on.

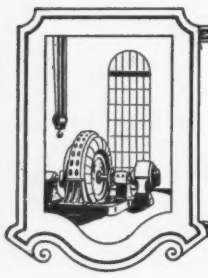
There was a crane already erected on the scow so that, with plenty of green logs for skids and rolls, we were able to get the boiler in place, bolted to the deck of the scow and the feed-pump connected the first day. Next, the engine and centrifugal pump were put aboard and the carpenters started to build a roof over the scow, for which I was most thankful, as the hot sun beat down on us unmercifully; it was extremely trying to a northern man. While this erecting job was going on, I was arranging a foundation of green logs for the small engine, on the bank, the same foundation serving for the separator machine.

In one week, everything was apparently ready to run. A crew had been cutting green wood for fuel. As the feed water had to be taken from the muck-hole, I had the carpenter build a filter-box at the end of the scow, using green hay for filtering material. The feed-pump was then piped to keep the filter-box filled, and an injector, which came with the boiler, was used to fill the boiler. At that, I had to blow down the boiler frequently. One of the colored men was kept busy feeding green wood to maintain 90 lb. of steam to operate the pump and the small engine on the bank. We finally started up, lowered the suction into water and started the priming syphon. As soon as the pump got water, and before the suction could be lowered into the mud, away goes the 14-in. belt off the pump pulley, rolling all over the deck. The belt was replaced, only to go through the same performance again.

The face of the pump pulley was flat and whenever the pump got a load the belt would run off, either to one side or the other. It so happened that there was some old 8-in. single ply belting in the junk, so I proceeded to "crown" the pulley. We sent to town for some belt glue and copper rivets. Two rows of ⅛-in. holes were drilled 6 in. apart around the face of the pulley and the leather was shaved thin on both edges of the top side. After the leather was glued smoothly, on the face of the pulley, in the exact center, it was secured with the rivets. We had no speed indicator, but the pump seemed to run a little slower. By adjusting the governor, and making some change in the lead on the slide-valve, I was able to get the pump up to speed.

When the pump was primed with water, the suction was lowered in to the mud and was kept constantly agitated by the crane tackle. It was claimed that 250 cu. yd. per hour was pumped. This muck was discharged to the machine on the bank through a long 10-in. pipe. The operation of this separating machine, I never learned. About every six days, it was necessary to replace one or more of the blades in the pump, as they wore out quickly.

I never learned how rich the "diggings" were. I only know they were not rich enough to pay my salary in full; at least I never got it.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Protection of Electrical Equipment---IV

CONCLUDING ARTICLE. PROTECTION OF ELECTRIC MOTORS. BY VICTOR H. TODD

ELECTRIC MOTORS may be divided into two general classes, direct-current motors and alternating-current motors. The latter group in turn may be divided into induction motors and synchronous motors. The general electrical ills from which direct-current motors may suffer

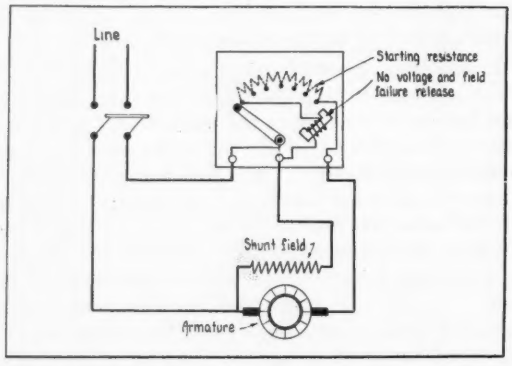


FIG. 1. DIAGRAM OF CONNECTIONS OF A SHUNT WOUND D. C. MOTOR

are excess temperature caused by continued overload, overvoltage or internal short or ground, commutator troubles caused by overload and loss of shunt field. In the smaller sizes, the correct application of fuses forms the most reliable and satisfactory protection, as the fuse has a thermal time lag, thus not blowing instantly on overload but allowing a short interval of time in which the overload may disappear and normal operation continue. This time interval is approximately inversely proportional to the amount of overload; for example, a 50-amp. fuse may take 10 or 15 sec. to blow when the current goes slightly over 50 amp. On 20 per cent overload, the fuse may take only 3 sec. On 50 per cent overload, it may take 1½ sec.; 100 per cent, 1 sec.; 200 per cent overload (300 per cent of load), ½ sec., and so on until, on exceedingly heavy overloads which approach short circuits in intensity, the time is almost instantaneous.

Great damage may be caused, however, by improper fusing, as it is a great temptation after the fuse has blown to substitute a larger size until finally the fuse no longer protects and the motor burns out. Of course, the obvious remedy is to find out why the fuse blows and remedy or remove the cause. One prolific cause of fuses blowing without apparent overload is imperfect contact, often between the fuse ends and the clips, and sometimes in the fuse block itself or in the connecting wires. This poor contact causes heating and oxidation which rapidly aggravates the difficulty, quickly causing the surrounding metal to become so hot that the fuse blows on normal load or less. A good rule to follow is always thoroughly to clean the contacts of fuses with knife or ferrule contacts, as well as the fuse clips themselves, with medium emery cloth every time a fuse is replaced and see that the ends are making good contact and that the clips have not lost their springiness or temper through overheating. A careful inspection should be made to eliminate loose connections either under screwed-on lugs or often due to poor soldering of the cable into the lug itself.

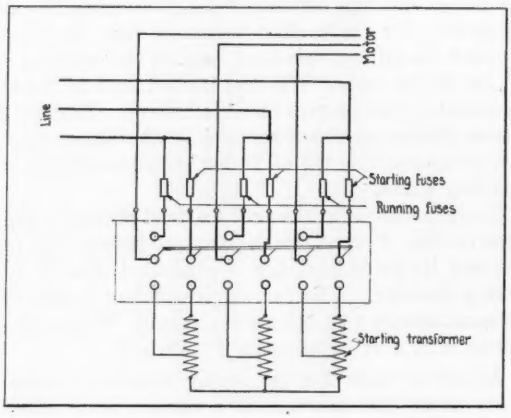


FIG. 2. A. C. STARTING COMPENSATOR WITH TWO SETS OF FUSES

When the size of fuses increases so that renewals become considerable expense, which point is in the vicinity of a 10 or 15-hp. motor, and where it is desirable to continue service with minimum interruption, then the automatic circuit breaker is used to take the brunt of the work, although fuses are generally also included to protect against breaker failure. This circuit breaker may be either an air break type, or an oil switch, and may be provided with attachments to give a time delay inversely proportional to the amount of overload, and with no voltage release, no voltage protection, or shunt trip coil for automatic or remote tripping.

One reason why fuses are often included is that with some breakers, they may be held closed by hand when the releases try to open them. A trip-free breaker eliminates this difficulty as in this type the releases trip the mechanism even though the handle be held in closed position.

In another type, the poles are separate and one handle is used to close them by turning "first to the left and then to the right," so that even should one pole be held in, the other will be automatic and trip out on overload.

Practically all d. c. motors are provided with starting rheostats to limit the starting current, and this rheostat is often provided with a no-voltage release coil which may be in series with the shunt field of the motor. This coil when energized holds the starting arm in the running position. But should the voltage fail, or the field circuit open, this coil is de-energized and the starting arm flies back to starting position, thus cutting the motor out of the circuit and preventing any damage to it. The diagram of connections of a d.c. motor is shown in Fig. 1, while the Underwriter's Rules should be carefully followed in determining the sizes of wire and the location of cutouts.

For example, a single-pole breaker would theoretically disconnect and stop the motor. Grounds are liable to occur, however, and for this reason a double-pole breaker is required.

In the larger size d.c. motors, especially where the speed, and consequently the field current, is subject to wide variations, it is generally advisable to use an underload d.c. relay in the field circuit. Then should the field become accidentally open-circuited at any point, this relay instantly closes its contacts (or opens them) and shuts off

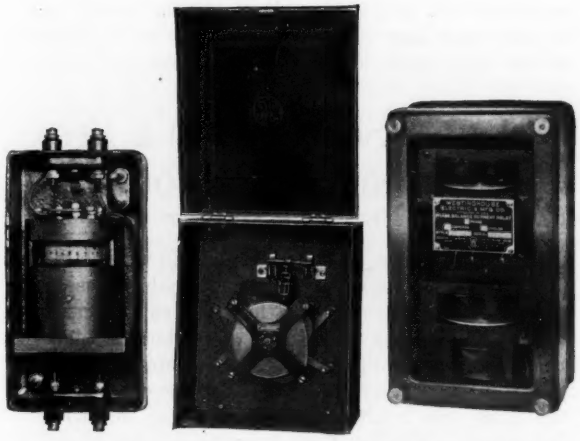


FIG. 3. LONG TIME DELAY OIL FIELD THERMAL RELAY
FIG. 5. PHASE FAILURE CURRENT RELAY
FIG. 6. PHASE BALANCE CURRENT RELAY

the motor before the armature speed and current can reach a damaging value.

Protection of Induction Motors

When an induction motor is started, it usually takes several times full load current for a few seconds. To provide fuses large enough to stand this would not give sufficient protection while running and this protection is the subject of much discussion. The safest practice, however, seems to be to provide two sets of fuses, located as shown in Fig. 2, one set for starting and one for running. The starting fuses, however, may be omitted if the next set of line fuses before the motor are sufficiently small to protect the motor during starting.

The larger motors are usually equipped with overload relays on their starting compensators, which may be of the solenoid and plunger type, the induction type or the thermal type. An interesting thermal type consists of a thin tube of mercury in series with the no voltage release. Around this tube is wound a heating coil which carries the load current, or a fraction of it if connected to the series transformer. When an overload occurs, this heating coil vaporizes the mercury, thereby opening the no-voltage release circuit and tripping out the switch. This cannot be started again until the outfit has cooled enough to liquefy the mercury again.

In another type, the current is passed through a special alloy wire with one end connected to a trip lever. When the current exceeds a predetermined amount, this wire expands enough to trip this lever, thus closing contacts which cut out the motor. This arrangement provides an inverse time action, is as accurate as the hot-wire type ammeter and the wires never heat to a point where they cannot be touched by the hand. On two-phase and three-phase circuits, two expansion wires are connected to a

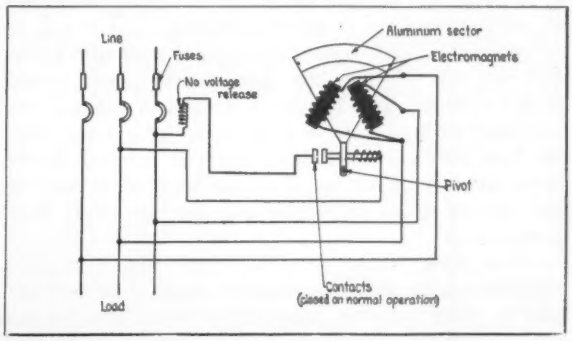


FIG. 4. CONNECTIONS OF REVERSE PHASE POTENTIAL RELAY

common trip lever, so that an overload in any phase will trip all connections to the motor.

Still another form of thermal protection used principally on small motors, is the plug cutout which contains two contacts held together by a fusible link. This element has considerable mass of metal to heat, thus giving it a longer time lag, but when it becomes heated, the alloy melts and the contacts fly apart. New alloy strips are easily installed.

Thermal Relays

Where the importance and value of the motor warrants it, unsurpassed protection from overloads may be obtained by the thermal relay with long time delay. It is well known that an alternating current motor need not be cut out until it reaches such a temperature as to damage the insulation, and also that this final temperature bears a direct relation to the integrated current which has passed. The object then is to get a relay which has the same thermal characteristics as the apparatus to be protected. For example, if the motor reaches a damaging temperature in three hours at a given load, then the relay should trip in 3 hr. If this temperature is attained in half an hour, then the relay should trip in half an hour.

Such a relay is shown in Fig. 3. It consists of several spiral springs of bi-metallic strip, all immersed in oil to give thermal capacity. The current passing through these springs causes them to turn until finally they close a contact which trips out the motor.

Thermal relays are meeting with more and more favor as their worth is recognized and in many instances, notably

in automatic stations, the temperature relays and schemes of protection described in previous issues have been installed with splendid protection.

Protection From Phase Failure and Reversal

Perhaps more motors have been burnt out from single phase operation than from any other cause. For example, if a motor is running polyphase, and one fuse should blow, the motor may not stop, but will draw a heavier load through the one phase and if the load be great enough and the protection inadequate will eventually burn out. A peculiar feature of this which should be clearly understood is that although a fuse may be blown and only single phase current flowing, yet from the generator action of the motor, polyphase voltage still exists on the motor side of the fuse as well as on the line side.

Therefore, there are two main classes of phase relays available: the polyphase voltage and the polyphase current relays. With the voltage relay and connections as in Fig. 4, the relay will not trip should a fuse blow while running as polyphase voltage is still maintained. But it will trip and prevent a motor from attempting to start with a blown fuse and will trip if a line phase should become reversed in any manner. This feature is valuable in elevator, mine, and hoist work, as it allows a car to run until it has reached its floor should a fuse blow, and will not stall between stops on power circuits. This relay should be used only for reverse phase protection and not for phase failure protection.

The phase failure relay, of which Fig. 5 is typical, contains two current coils which act on an aluminum sector and by their inherent phase displacement and induction action, keep the contacts open. Now, should only a single-phase current flow, the polyphase torque disappears and the disk or sector, sometimes assisted by shading coils, swings over and closes the contacts. This relay also protects from reversed phase as it trips the instant an attempt is made to start the motor.

Severe unbalancing may also cause damage and is of course indicative of an improper condition. To protect against this, the phase balance current relay was developed, and is shown in Fig. 6. This has two induction movements, each with two current coils, pulling in opposite direction. For example, current A is bucked against current B in one element and current B is bucked against current C in the second element. Thus when all currents are equal, the disks stay in a central position but when any current goes higher or lower than its mate, then the disk swings around and either cuts out the motor or sounds an alarm.

Protection of Synchronous Motors

One of the most favored protection methods of synchronous motors is by the use of thermal relays, exploring coil outfits and temperature load relays. In this latter type, the tripping occurs only when a heavy overload occurs on a hot motor. For example, a motor will not trip no matter how hot it is, unless the current is high, and it will not trip no matter how high the current is unless the temperature is high.

When overload protection is provided, it takes a special form. For example, an induction relay may be provided to give an inverse time up to the load at which the motor will pull out of step. Then there is an instantaneous relay provided so that the instant the motor throws out of step, this relay will trip and cut it out of service.

Protection From No Voltage

If the line voltage fails for more than a second or so, the motors will tend to stop and then if the power comes on suddenly and if they are still connected, it may cause considerable damage. For this reason, the starting compensators of the small and medium size motors are provided with no-voltage releases which disconnect the motor by returning the handle to the off position when the voltage fails.

Larger size motors are provided with more accurate no-voltage or low voltage relays which may be set to trip when the voltage merely drops to, say 75 per cent of normal.

Distinction should be made between no-voltage release and no-voltage protection. The first is used on automatic machinery such as blowers, air compressors, and such apparatus which must be kept running continuously and automatically. With the no-voltage release, when the voltage fails, the starter returns to starting position so that when the voltage comes back, they will start automatically.

But with the no-voltage protection, when the power fails, the starter returns to off position, and someone must start it again manually when the power returns. This is used on all classes of apparatus where someone may start working on it when the power fails. For example, a workman may start repairing a belt or removing a circular saw and it is evident that the motor must be so protected that it cannot suddenly be automatically started by a return of power to the lines.

Trouble Shooting on a Freak Electrical Layout

By Fred S. Rutledge

NOT LONG ago, in a certain plant in which all equipment is electrically driven, trouble was experienced in certain sections of the electrical system due to the motors blowing their fuses, and after the fuses were renewed the motors would refuse to start. Of course, this resulted in great excitement and everybody around the place was frantically trying to find out what was the matter. Finally, I sat down to get my breath and then started tracing out the feeder lines to the distribution boxes and discovered rather an unusual layout. This layout, which is shown in the sketch, was put in during the war and the size wire and conduit required to carry the current not being obtainable, 2-in. conduit was used instead, and two runs provided for each phase. Two wires were pulled in each run, making 18 2-in. runs of pipe from the transformer house into building B, and a total of 36 wires in the three lines, 12 per phase.

Line A feeds half of building A and line C feeds the other half. Building B is fed from A, B and C lines. In building B, three of these lines, A, B and C are brought together and connected to the terminal of a 400-amp., 250-v. fuse block, through which they feed three wires to building C.

This was almost enough to make a man wish for home and mother, but the fun had only begun. If pulling the fuses at E would have separated the lines and made them all feed through their individual fuses at D 1-2 and 3. the task of shooting the trouble would have been easy, but with a bundle of 12 wires connected together to get

them into one connection or block, terminals of blocks at E making bundles, one for each phase, all the same size, the job of separating them looked too big. Why the blocks at F were installed, I cannot understand. The way it was working was as follows: A number of motors on line A would blow their fuses. After putting new fuses in and starting, motors on line B would blow their fuses. About this time a 20 hp. motor in building B blew its fuses and all motors in building C did the same. If we tried to test the main line fuses at D 1-2 or 3 with a test lamp in the usual way, they tested good, always.

Finally I had every motor shut down that fed off these lines and began work by pulling the 350 amp. fuses at D 2 and found one of them blown. This was determined by putting one end of them on one blade of a knife switch and the test lamp from the other end to other switch blade. So far, so good. I got them fixed and then tried D-1 in the same manner. I found one fuse blown there. Just got that repaired and somebody got busy and started some motors in building C and blew 2 fuses on D-1 and 1 on D-2. I cut the power off entirely, and found that there were 2 fuses blown on D-1 and D 2-1 on D-3 block, two 400 amp. fuses on block F and one on block E.

This layout seems to feed around in any direction as long as there are any fuses in working order or any one of the three separate blocks. One fuse will blow and throw an increased load on the corresponding phase of another block until that blows. The motors are all induction motors and they run 2-phase when one fuse blows until they blow the rest of the fuses on their line. Then when the blown fuses are renewed, the motor will not run, but if there are any other motors running anywhere on these parallel lines, the blown fuses cannot be found on the feeder lines A, B and C until every motor connected in buildings A, B and C is shut down. I have been around this layout a long time, in fact ever since it was installed, but never had occasion to investigate it before.

At the time it was installed, there was a new engine and generator put in and the job of electrician and engineer were separated, as the buildings and motors are considerably scattered. The original power installation was a poor job that was about ready to break down and on top of that the transformers were located on the fourth floor of the building farthest from the engine room. In fact, the electrical inspector condemned the location and made them install the transformers in the power house, which meant reversing the electrical distribution system.

The superintendent thought it would be better to give the electrical end of the work to another man and the steam end remained in my charge. This layout is one of the results and while there may be others just as bad, I have yet to see one that has it beat, for locating trouble.

At the time the transformers were moved the company received estimates on the job from several electrical contracting companies and also the length of time required to do the job. One week was the shortest time any of them wanted. That was too long a time, so the man who took charge of the electrical work, another man who was handy at that work and myself took charge of the job on a 3-day limit. We had help to get the transformers down from their previous location, which was done by disconnecting the two 75-kv.a. transformers and leaving the 100 kw. connected up until we got the two down on the elevator and the car hauled back up. Then the other one was cut out and loaded on the elevator, which was sent down by turning the worm shaft with a pipe wrench. We had it down by the time the gang got the two small ones unloaded and pushed into their new location.

We then took the 100 kw. transformer over to the new power house.

The start of unloading these was made at 12:30 p.m. on Saturday, and Monday morning at 7 a.m. they were all hooked up and ready to run.

Just to give some idea of how tired we were, the handy man was sweating lugs on wires and went to sleep holding a lug in a pair of pliers and got his wrist in line with the flame of the blow torch, burning him badly. We put on some ointment from the first aid cabinet, bandaged it up and went on working. He worked as long as the rest of us and when he got back on the job Tuesday morning, he could not remember how it occurred. Forty-two and one-half hours was the actual working time put in on the job by three men, and 4½ hr. by three helpers and one team, to move the transformer. This was October, 1917, and there has never been any trouble with the installation on account of the workmanship. Some work had to be done in the transformer house in 1921, but that was on account of lightning getting through clear to the switch panel. There were cut-out fuses on a pole, outside the house, high tension expulsion fuses, choke coils and lightning arresters, between them and the switch panel, but the discharge went through everything and set the oil afire in the oil switch on the back of the panel. Thirty hours were required to repair this damage.

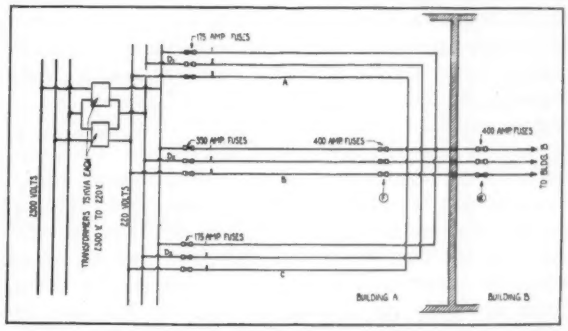


DIAGRAM OF THE FREAK ELECTRICAL SYSTEM

DAMPERS ON OIL FIRED boilers should not be fitted too closely for the reason that there is danger of one or more fires becoming extinguished and the fuel oil from the burners forming explosive gases when coming in contact with the heated brickwork. There is also danger due to the possible existence of leaky burner valves, which when the fires under a boiler have been extinguished and the boiler closed up, leak oil onto the heated brickwork. For these reasons there should exist sufficient air leakage past the damper to clear the boiler and economizer of all such combustible and explosive gases.

Right Plans Essential in District Heating

RATES MUST GIVE PROPER RETURN. SYSTEM MUST BE PLANNED FOR ECONOMY AND MAXIMUM REVENUE FROM BUSINESS. BY H. R. WETHERELL*

FROM THE standpoint of the customer, there is no doubt that district heating service is desirable and, if the distribution system and plant are installed in an efficient manner and if equitable rates are charged, it can be made a paying investment for the operating company.

Central station service has always been desirable to the customer but, in the past, it has been considered a poor investment for the operating company, due to the extremely low rates established for this service and in some cases the inefficient management and lack of knowledge of the important features in the operation of such a business which would tend to increase the earning power of such an investment.

The flat rate system of charging and the low meter rates which were established when the district heating industry was first introduced had much to do with the failure of companies to operate on a profitable basis. The majority of the district heating properties which are now being operated were originally built with the idea of using the exhaust steam from electric generating stations and, as this steam was considered of little value, the rates were based proportionally. It was not considered that, as the heating business grew, making it necessary to carry higher pressures in the steam mains, the back pressure on the engine would be increased and the electric efficiency reduced. It was also found that the electric and heating loads did not balance and, as the heating business grew, it was necessary to add extra boilers to take care of this load, using live steam during the colder months and at certain times of the day throughout the entire heating season, when the electric load did not furnish enough exhaust steam to supply the heating demand. As the years progressed, the electric load, particularly in the larger cities, grew far beyond the heating load and it was found necessary to install 10,000, 15,000, 20,000 and even 30,000-kw. units which, operated with condensers, had a much lower water rate than the small simple engines or non-condensing turbines formerly used. This led the men operating these plants to be of the opinion that the heating load was a nuisance and that the small electric units which it was necessary to maintain to exhaust into the heating system cut down the efficiency of their electric operation.

Installation of the larger condensing units, with which the large bulk of the current is generated, in plants where the fuel and other operating costs are pro-rated between the heating and electrical departments on the basis of the coal used per kilowatt-hour have caused a greater amount of coal to be charged to the heating departments, due to their higher efficiency. It will, therefore, be seen that, in such plants, the cost of the steam delivered to the heating mains has gradually increased, due to the electric development without any material change in the heating department. As the heating rates were originally based on a division of the costs, when small non-condensing units were used with much higher water rates, the development of the electric industry has changed operating conditions so that the original rates established for this service are entirely too low.

During the World War and the period immediately following, the flat rate system of charging was eliminated and new meter rates established, allowing a fair return on the money invested, so that today the majority of the companies engaged in this business are operating on a sound business basis. With the prices of coal which prevail today and with a properly designed and operated property, it is possible to obtain rates high enough to pay a fair return on the investment, yet to serve customers for less than the physical cost of operating their own plants.

In comparing the cost of central station service with the cost of operating an isolated plant, many advantages are gained through the use of this service which cannot be set up in dollars and cents, and which are listed as follows:

No ashes to remove; no boiler to install; no depreciation of apparatus; increased value of real estate; no fires to be built and looked after; abatement of the smoke nuisance; easier to secure and maintain help; increased salability of property; reduction of fire risk and therefore of insurance; supply of heat at all hours every day of heating season; much more satisfactory service than individual heating affords; life and health not jeopardized by coal gas and boiler explosions; increased cleanliness due to the absence of coal, smoke, and ashes about the building; stores, offices and residences more rentable and always occupied in preference to others; increased amount of valuable space in buildings due to absence of boilers, coal bins, ash piles, etc.; cost of heating divided into as many bills as there are months in which the service is rendered and payments made after the heat is used, instead of paying for coal in advance of heating season.

One of the important factors in the successful operation of a district heating company is the installation of the proper type of system in the customer's building and the education by the operating company of the customer as to the proper regulation of his service to obtain the maximum efficiency at a minimum cost. Various heating systems and mechanical devices are available at the present time which, if installed and operated in the proper manner, will extract all of the valuable heating units from the condensation before it is discharged from the customer's building into the sewer. This problem is of greater importance in buildings supplied from a central heating plant than in buildings having their own boiler plant for, in the latter case, the condensate is returned to the boiler to be regenerated into steam and the heat units remaining in the condensate after it has passed through the radiators are not lost, as is the case when the condensate is discharged into the sewer.

Heat can be easily wasted in buildings supplied from a central station by leaving the steam in the building over night when it is not needed, while this waste is automatically eliminated by the banking of boilers in buildings applied by their own plants. New customers taking central station service, after having used their own plants for a number of years, invariably use steam a greater number of hours each day than formerly.

In business buildings which have their own heating plants and are occupied from seven in the morning until

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six in the evening, the average firing period is 2500 hr. a year, while those buildings purchasing steam from a central station have steam available 24 hr. each day from Sept. 15 until June 1, or a total of 6000 hr. It can be readily seen therefore how easy it is for the customer to use steam from central heating plants a greater number of hours a day than steam supplied by his own plant.

There is much more to the building and successful operation of a district heating system than the mere laying of the mains in the streets, the connecting of one end to the power plant and the running of services into the buildings to be served. The district to be served should be completely surveyed as to the amount of present and future business which can be obtained. Distribution mains should then be designed to take care of this load, looking ahead 25 or 50 yr., if possible, and the limit boundary lines established. The first year's installation should cover that portion of the district which will afford the maximum amount of immediate business, further extension and tie lines to be made each year as the business is available. No extensions should be made, however, unless the revenue to be obtained from the business to be served is sufficient to stand its portion of the fixed charges.

Due to the extremely high cost per foot of steam mains laid in the public streets as compared with similar costs of other public utilities, it is necessary that the distribution system be loaded to as near the saturation point as possible in order to obtain a proper return on the investment. The manager of such a utility should not, in his enthusiasm to load up his mains, take on buildings which have insufficient radiation to heat them properly, or small pipe lines or pockets in the supply and return lines requiring high pressures to circulate and heat the building properly.

In order to give first-class and efficient service to a building, it is necessary that sufficient radiation be installed in all parts of it to maintain the desired inside temperature during a period of the lowest outside temperature. The piping should also be installed of the proper size and graded so that steam will circulate through all parts of the system with a pressure of 1 lb. or less at the service valve. If buildings are not so equipped, it is impossible to shut steam off at times when the buildings are not occupied and reheat them in a short period of time.

A building requiring high pressure might also be located at a remote distance from the plant, making it necessary to carry high pressure throughout the entire distribution system to serve this one building. Such a condition would increase line losses and if underground mains were supplied with exhaust steam, would increase the back pressure on the engines or turbines.

Points mentioned in this article are but a few of the many which must be taken into consideration in the successful operation of a district heating plant and failure to observe these points has been a factor, as well as the insufficient rates, in the unsuccessful operation of this industry. If these facts are considered in the future development of district heating plants, it is reasonable to assume that a satisfactory return can be had on the money invested in these projects.

Use of Centrifugal Pump Curves

USUAL FORMS OF CHARACTERISTIC CURVES FOR CENTRIFUGAL PUMPS ARE BASED ON CONSTANT SPEED

SUITABILITY of a pump for a given service is based upon the relations of head, capacity, speed, power and efficiency. These are what may be called fundamental variables and they are of great importance not only to the manufacturer of this equipment but also to the prospective buyer and the operator.

These variables, when plotted on cross section paper, are known as characteristic curves. The most common curves are those showing head and capacity together with efficiency and brake horsepower. In so far as practice is concerned, the relations between these quantities are absolutely fixed for a given impeller, the pump designer, however, may so proportion the impeller diameter and angles that he can obtain as great a variety of different characteristics are may be required by the conditions under which the pump will operate.

Usual forms of characteristic curves for centrifugal pumps are based upon a constant speed of the pump, the curves showing the relation at that speed of the head, capacity, horsepower and efficiency. It is of course often necessary to work up curves for a given pump so that its characteristics may be studied at various speeds.

When purchasing a new pump, it will always be advisable to adhere to the manufacturer's recommendation as to speed for the reason that he has designed the pump for the speed which will give the best results. It often happens, however, that old pumps can be speeded up or that a change in the drive will call for some speed different from that at which the pump was originally designed. In cases of this kind it is of great advantage to be able to obtain from the manufacturer a curve showing the characteristics of the pump at the new speed.

Referring to Fig. 1, it will be noticed that three curves are shown, one representing the total head, another showing the brake horsepower and a third curve showing the efficiency of the pump. Nothing is said about the speed of the pump which in this case is constant, that is the curves show the relations of the three variables mentioned above when the pump is being driven at a constant speed. In this particular case the pump was rated at 2800 g.p.m. against a head of 50 ft. This is at the maximum efficiency of the pump as is shown by the fact that the efficiency curve reaches its highest point at that rating. At that rating the efficiency of the pump would be about 80 per cent and the horsepower required to drive the pump would be about 63.

Now if, for some reason, the head on this pump should be increased to 70 ft., the speed of course remaining the same because we are dealing with the same constant speed curves, the horsepower would drop to about 43 and the efficiency would drop to about 60 per cent. This would not tell the whole story for reading down on this co-ordinate it is found that under the new conditions the capacity of the pump has dropped off to 1500 g.p.m.

Characteristic curves are made up by the manufacturer in a test laboratory specially equipped for this work. The pump to be tested is set up with a valve on the discharge line. Some means of driving the pump is arranged for so

that a record may be made of the horsepower actually required. The necessary points for plotting the curves are obtained by bringing the pump up to speed with the discharge valve closed and measuring the total head, the discharge in gallons per minute and the brake horsepower for successive openings of the discharge valve. The efficiency is then calculated for various points from the formula:

$$\text{Water horsepower} = \frac{\text{discharge} \times \text{head}}{33{,}000}$$

$$\text{or water horse power} = \frac{8.33 \times \text{G.P.M.} \times \text{Total head in ft.}}{33{,}000}$$

$$= 0.000{,}252 \times \text{G.P.M.} \times \text{total head}$$

$$\text{The efficiency would then be} = \frac{\text{water horsepower}}{\text{brake horsepower}}$$

Referring again to Fig. 1, it is evident that as the total head is decreased by opening the discharge valve, the quantity of the water discharged increases and the efficiency and brake horsepower rise. The two last items

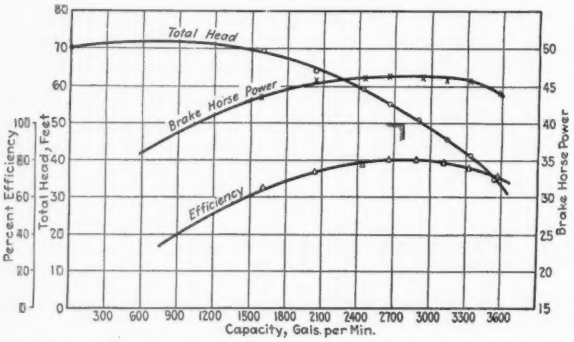


FIG. 1. CHARACTERISTIC CURVES OF A CENTRIFUGAL PUMP RATED AT 2800 G.P.M. AND 50 FT. HEAD

reach a maximum at the point for which the pump was designed and then decrease with a further increase of capacity. The original characteristics of a centrifugal pump will be maintained so long as the impeller does not become worn, the sealing rings do not become worn and the glands are properly packed and sealed. Water containing sand and grit are the worst enemies of the centrifugal pump. When the water being handled by the pump is unusually bad, it will be advisable to supply the glands with clean water from some independent source.

In Fig. 2 are shown the characteristic curves for a boiler feed pump rated at 450 g.p.m. at 1750 r.p.m. against a total head of 460 ft. These curves were made from a 3-in., 5-stage pump. They are interesting because they show the non-overloading runner characteristic and the wide range of high efficiency, both of which are desirable in a boiler feed pump.

Efficiency curves always start from zero at zero capacity, which must be the starting point because the pump does no useful work until it discharges water, although it consumes power which is lost in friction due to the churning of the water. Serious damage may result to a centrifugal pump by allowing it to run with the discharge valve closed. The friction of the runner and water will generate heat which will expand the runner and shaft, causing them to rub or grip, thus causing the pump to freeze.

Again considering the curves of Fig. 1, it will be noted that the pump was originally designed to deliver 2800 g.p.m. against a total head of 50 ft. If this pump had to work against a total head of 60 ft. it would deliver only 2300 g.p.m. If it was desired to remedy this condition and obtain the original capacity, it would be necessary to do one of three things, increase the speed of the pump, decrease the head or install a new impeller.

Determination of the Total Head

This leads up to one of the most important points to be considered when selecting a centrifugal pump, namely, an accurate determination of the total head against which the pump must work. The correct determination of the head against which a pump operates involves four items, suction lift, discharge head, friction head and velocity head.

Suction lift is the vertical distance, measured in feet, from the level of the water to be pumped to the center line of the pump. If the water level is above the center line of the pump the pump is then said to work under a suction head and the distance from the water level to the center line of the pump must be subtracted from the sum of the three remaining elements.

Discharge head is the vertical distance, measured in feet, between the center line of the pump and the level to which the water is elevated. Friction head may be determined by the use of charts or tables, to be found in any standard handbook, which give the approximate losses in pipe lines for different sizes and capacities.

Methods of estimating frictional losses, especially in elbows and valves are necessarily approximate for they depend upon many variables such as smoothness of pipe, length of time it has been in service, radius of bend, etc. It is customary to estimate the maximum possible loss and then allow a slight additional amount for safety, which results in the specifications calling for several more feet of total head than are actually required.

Head due to velocity, or simply velocity head, is the equivalent head through which the water would have to fall in order to acquire the velocity at a given point. When the velocity in feet per second is known, the velocity head (h) in feet is determined by solving for h in the formula

$$h = \frac{v^2}{2g}, \text{ in which } g \text{ is the acceleration due to gravity}$$

or 32.16 ft. per sec. and V equals the velocity of the water in the discharge pipe in feet per sec. The actual value of the velocity head is usually small and so in most cases need not be considered. It is of greatest importance when the total head is low and the suction head high, or in very accurate testing.

When calculating the total head on a centrifugal pump having the same size suction and discharge pipes, it is necessary only to calculate the velocity head for the suction side of the pump. If the discharge pipe is smaller than the suction pipe, as is generally the case, the velocity head should be computed from the velocity at the discharge nozzle of the pump.

Characteristic Curves at Varying Speeds

It is often of value to consider characteristic curves for a given pump or impeller at varying speeds. The law governing the relation between head and capacity for a given impeller at varying speeds has been fully verified by a great many tests. Briefly stated the law is as follows:

The total head varies as the square of the speed and at the same time the capacity varies directly as the first power of the speed.

This law is general and is independent of the type or proportions of the impeller under consideration, it ceases to be true only when the entrance velocity exceeds 16 to 20 ft. As these velocities are well above those used in actual design, the ordinary range of commercial conditions are unaffected.

Application of this law may be shown as follows: Suppose that at 1200 r.p.m. and 60 ft. head a given pump has a capacity of 3000 g.p.m., then at 1500 r.p.m. the pump will deliver $3000 \times \frac{1500}{1200} = 3750$ g.p.m. and it will develop a total head of $60 \times \left\{\frac{1500}{1200}\right\}^2 = 93.8$ ft.

We may now consider the effect of a change in speed on the efficiency curve, which is determined from the following: after a change in speed the relative efficiency of each point on the head capacity curve remains the same as before. By relative efficiency is meant the efficiency of a particular point in per cent of maximum efficiency at the same speed. The actual efficiency after a change of speed may actually be slightly higher or lower than before the change in speed was made. This is a matter of impeller design.

For instance we may assume that by test it has been found that the maximum efficiency at 1000 r.p.m. was 75 per cent and at 1200 r.p.m. 80 per cent. We may now consider the point at the lower speed where the pump delivers 1600 g.p.m. against a total head of 45 ft. We will say that the efficiency at this point is 70 per cent. Our efficiency test curve at the lower speed reached its crest or maximum at 75 per cent, therefore the relative efficiency at that point is $\frac{70}{75} = 93.3$ per cent.

At 1200 r.p.m. the point in question becomes $1600 \times \frac{1200}{1000} = 1920$ g.p.m. and $45 \times \left\{\frac{1200}{1000}\right\}^2 = 64.8$ ft. head. The maximum efficiency of the impeller at 1200 r.p.m. being 80 per cent, the efficiency of the point under analysis would be $0.80 \times 0.933 = 74.6$ per cent. In practice pumps designed for heads less than 100 ft. the efficiency will be slightly higher for moderate increases of speed and slightly less for moderate decreases in speed. For this reason but slight error will be increased if the efficiency of corresponding points is assumed to be the same.

Next to be considered is the change in the brake horsepower curve resulting from a change of speed. Since with changing speed the capacity of a centrifugal pump varies as the first power and the head varies as the second power, it is evident that the brake horsepower which is a function of the product of the two will vary as the third power or cube of the speed. This is of course based upon the assumption of constant efficiency during the change of speed. In our previous problem the change of speed was from 1000 to 1200 r.p.m. Now if our characteristic curve at the lower speed had shown for a given capacity a brake horsepower of, say, 30, under the new condition of higher speed the brake horsepower would be $30 \times \left\{\frac{1200}{1000}\right\}^3 = 51.8$. This would be the brake horsepower required to drive the pump at 1200 r.p.m. under which conditions it would deliver 1920 g.p.m. against a head of 64.8 ft. and at an efficiency at about 74.5 per cent.

To obtain the maximum efficiency of a centrifugal pump would be a comparatively simple matter provided that a pump casing could be designed for each different set of conditions so that the best entrance and volute velocities could be obtained in each case. This is not practicable, however, from the commercial standpoint for it would greatly increase the pattern work to be done and so add considerably to the price of each pump to the purchaser.

Relation Between Size of Pump and Capacity

Until recently it was thought that the size of the pump to be used depended only upon the capacity. It is now recognized that an increase in efficiency can be obtained for many conditions by using a different size casing for the same capacity, this being dependent upon the total head to be worked against and the speed at which the pump is to be run.

In general it has been found that the higher the total head and the speed the higher the entrance and volute

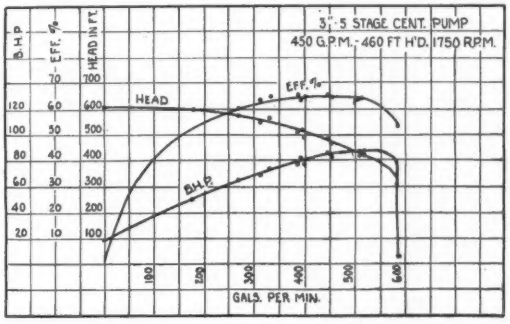


FIG. 2. CHARACTERISTIC CURVES OF A FIVE-STAGE PUMP, RATED 450 G.P.M., 460 FT. HEAD AND 1750 R.P.M.

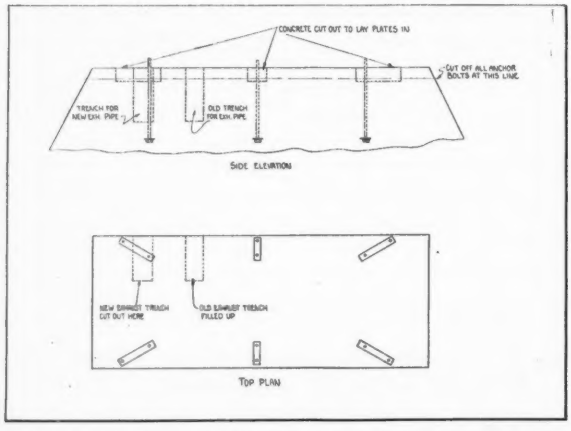
velocities should be if a maximum efficiency is to be obtained. To illustrate, assume a pump of 9000 g.p.m. capacity. At one time this was supposed to call for an 18 in. pump for all conditions. While this was true for low heads of say 30 ft. or so, it has been proven by test that for a head of 70 ft. it is possible to obtain 4 or 5 per cent higher efficiency by the use of a 16-in. pump. This change also results in a saving of 8 or 10 hp. as well as a lower price. The smaller pump will operate at a higher speed thus effecting a further saving in the size of the driving unit. The converse of this is true for extremely low heads where it has been found that a better efficiency can often be obtained by the use of a larger size pump that was formerly considered standard practice.

The question of the exact point at which it is desirable to change the pump size to obtain the best efficiency is not determined from theoretical considerations. It is dependent upon a study of experimental data and the standards and constants in use by the various manufacturers.

For a full consideration of these points, it will be seen that it is advisable to leave the selection of speed up to the manufacturer. If the purchaser insists upon a certain speed it is likely to happen that a pump will be installed which will operate at a lower efficiency than that which could have been obtained. Once the pump is in there is a constant additional operating cost due to this lower efficiency.

Making Old Foundation Serve for New Engine

TO INSTALL an engine on an old foundation, the anchor bolts of which do not fit the new engine is not an easy job at any time but when the factory work is held up while you make the change, the difficulty is increased because of the care necessary and the limit of time. The accompanying sketches show how such a job was done. The old foundation was large enough for the new engine although the old engine was too small for the work required.


CONCRETE CUT OUT TO LAY PLATES IN
CUT OFF ALL ANCHOR BOLTS AT THIS LINE
TRENCH FOR NEW EXH. PIPE
OLD TRENCH FOR EXH. PIPE
SIDE ELEVATION
NEW EXHAUST TRENCH CUT OUT HERE
OLD EXHAUST TRENCH FILLED UP
TOP PLAN

PLATES WERE USED TO ADJUST THE POSITION OF THE NEW FOUNDATION BOLTS

Trenches were dug down in the concrete, deep, wide and long enough, so that the old anchor bolts were cut off below the surface of the foundation and threaded again. Iron plates were made of 2½ by 4-in. material and drilled on one end to go over the old anchor bolts. The other end was drilled and tapped and a stud, threaded on both ends was screwed into it and riveted over.

To accommodate the exhaust pipe a new trench was cut out and the old one refilled with concrete. The short studs in the ends of the plates were made 18 in. longer than was required when the engine was down on the foundation and that left room under the frame, after the bolts had been entered in their respective holes, for a man to get under it with a socket wrench, and tighten up the nuts on the old anchor bolts, which had been left loose so that the plates could be moved to get the studs lined up. The socket wrench which was used we made out of pipe using a 36-in. chain tong for a handle. After tightening up the nuts concrete was poured in the trenches on top of the plates till even with the top of the foundation.

This job was done about 15 yr. ago and a person who did not know it could never tell but that the anchor bolts were put in in the usual way. The new engine has been heavily overloaded for several years but appears to be as solid as the day it was started. To thread the old anchor bolts, after they were cut off and still not have to cut out too big a hole in the concrete. A piece of pipe, big enough to go over the die, was slotted in the end so that the handles of the die stuck through and then we had to cut them off some, so that they would not hit the sides of the trench. A hole was bored in the other end for a bar to go through, to turn it by.

Minneapolis, Minn. FRED S. RUTLEDGE.

Acetylene Welding in the Plant

DURING THE past few years an enormous increase in the use of acetylene welding apparatus has been noted. The endless uses to which it was put during the late war and its apparent superiority over older methods, have gained for it a much deserved popularity. As a result, there are shops that make a specialty of this method of welding and brazing.

The surprising part of the situation is that more manufacturing and power plants do not take advantage of this method of welding metals. There is hardly a plant operating that could not use acetylene to advantage and the savings effected by its use make the outfit a profitable investment. The reason often advanced for not installing a welding outfit is that no employe about the plant is capable of operating the apparatus to advantage and they do not feel justified in hiring an experienced welder. Where there is not enough welding work to keep one man busy, this is not at all necessary. Anybody about the plant mechanically inclined and possessing the ambition to learn can, in a reasonably short time, master the rudiments of welding and brazing.

Once a welding outfit is put to work, its convenience becomes apparent. Numerous jobs about the plant that have been put off from time to time because of the work or expense involved are undertaken and the work is simplified by the aid of this apparatus.

In the engine room it provides a quick means for returning to service broken parts of machinery. Cracked pump castings are often welded and saved from the scrap heap. As the outfit is portable, the torch forms a handy means of applying an intense heat to any particular spot that may need heat, the rest of the work being kept cool by pouring water over the work. This feature of being able to apply heat at the desired point only is often useful in straightening rods and other parts of equipment sprung out of true.

Steam headers that develop leaks about the flange threads are often welded, permanently stopping the leak and saving the expense and labor of installing a new section of pipe. A 16-in. exhaust line from the main generating units in a certain plant developed a leak by rusting through, caused by a water drip. Otherwise the pipe was

in good condition. A circular patch 10 in. in diameter made of ¼-in. sheet steel was welded on, the time required being about 1½ hr.

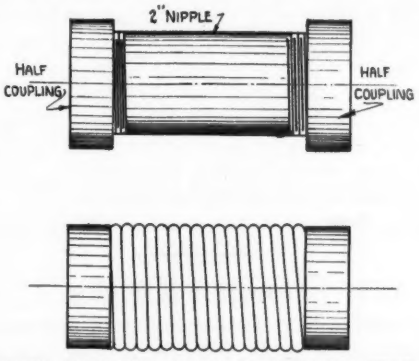
Welding outfits usually include a cutting torch by means of which cutting is done. With this cutting torch it is a simple matter to cut to any shape or dimension almost any thickness of sheet steel. Boiler tubes can be cut out in a few minutes, making the work of removing the expanded stubs a simple matter.

Considering the countless uses for the apparatus found about a plant, one often wonders how the modern plant can manage to get along without it.

Louisville, Ky. A. R. KNAPP.

Plug for Defective Fire Tube

NOT LONG ago I saw a novel kink developed for stopping a leak in one of the tubes of a fire tube boiler. The leak was in a 3-in. tube several feet from the front end. A 2-in. coupling was cut into halves and each half was screwed onto a 2-in. nipple 6 or 7 in. long. Some cotton wick was twisted and soaked well in a mixture of red lead and oil and rolled tightly onto the part of the nipple between the coupling halves as shown in the accompanying



NOVEL PLUG FOR A BLOWN OUT FIRE TUBE

sketch. The plug was then driven into the tube with a long piece of 2-in. pipe until the wrapped part covered the hole and stopped the leak.

The kink impressed me as having several advantages over the method often used of plugging both ends of a tube when a hole blows. The draft is not affected, there is no chance of blowing the plug out and the escaping water will force the strands of cotton wicking towards each coupling half thus preventing any leakage towards the tube ends, and keep the cotton wick wet enough to prevent burning.

Toronto, Ont. JAMES E. NOBLE.

Getting Properly Started

IN THE April 1 issue of the paper there are two editorials that particularly aroused my interest, namely, "Comments From Readers" and "Something Wrong." In the first editorial referred to an invitation is given for expressions of opinion from readers of the paper who may not agree with the opinions of the various writers who contribute from time to time to these pages. I presume the editor will not be averse to receiving comments that are in agreement with what has been stated, and so I take the liberty of expressing an additional opinion to what was stated in relation to the second editorial referred to, "Something Wrong."

I quite agree with all that was said in that article, for in past years I had been a "shop" man and know the ways of the boys and men who are known as "mechanics" and "tradesmen," therefore, I feel that I may safely express an opinion relative to the matter.

Power plant engineering as a whole has many subdivisions. There are some trades that are directly related to engineering, and some only indirectly related. The men in the "trades," otherwise the "mechanics," form one group, the regular full fledged engineers form another group, and generally speaking there is a sharp line drawn between these two groups. The editorial refers to some one in the steam fitting subdivision of engineering, but what was said in that connection is just as true and applicable to the other trades that are connected with engineering.

Boys who enter the various trades related to engineering have different ultimate objects in view. Some become apprentices with the idea of becoming master workmen in their chosen craft. They like the work. They are interested in all that pertains to the work. Nature seems to have fitted them for that particular line of endeavor. So they succeed. Not only do they ask questions about their craft, but they virtually insist upon, and demand answers. So they progress, eventually become foremen, and sometimes higher in their particular trade.

Other boys become apprentices in the various trades merely to "get a job." They have no particular interest in the work itself and use it only as a means to obtain money. They are satisfied to do as little as they can get away with and not do that little well. They seldom ask questions about the various features of their work and, even if some kindly disposed person volunteers information, it is received indifferently and sometimes not at all. Such boys grow up and become indifferent workmen, knowing only the barely necessary things to enable them to hold their jobs.

There is still another class who become apprentices to a trade with the sole object in view of using the knowledge so gained as a stepping stone to something higher and outside the limitations of a trade. These boys are not satisfied with merely knowing how to perform a certain "job," they want to know the "why" and "wherefore" and all concerned. They want to know the theoretical and technical features as well as the practical shop work methods. This requires a long time and much thought and study outside shop hours. It requires pluck and ambition on the part of the fellow who tackles it. But in time such a boy becomes a real engineer. He goes through the various steps and grades, educating his head as well as his hands. He becomes expert with tools and all that pertains to actual work in the shop, moreover he learns how to think, reason, plan, direct, supervise engineering undertakings, in short he is an engineer. Such a fellow becomes an engineer at the top of his chosen branch in spite of all obstacles that may have been in his way throughout. He was bound to succeed, counted the cost, satisfied to attain a certain position and gets it. He is a very different kind of man than the ordinary shop mechanic with whom he at one time was associated, and whom he has left so far behind on the road to achievement.

It seems to me that the crux of the matter we are discussing is this: The various trades related to engineering offer little—if any—incentive to the several workers to progress beyond a certain fixed job. They are satisfied to learn just how to do a certain work for which they receive a certain wage, and that is about all there is to it.

They are not expected to know more and don't and so they get no more and no farther ahead.

On the contrary, the fellow who aims to become an engineer in any particular branch of engineering, is compelled to do more than just work with his hands and with tools. He must study outside of regular working hours while he is getting the practical part of his training. He must ask questions, demand answers, seek information wherever and whenever he can. But, to follow such a rigid program the candidate for ultimate high honors must be willing from within, rather than be forced from without, to endure to the end. This willingness, ambition, insistence, is what distinguishes the engineer type of fellow from the other type of which there are a goodly number in the trades.

Brooklyn, N. Y. CHARLES J. MASON.

Check Valve Troubles

ONE OF the 1½-in. check valves on the boiler feed lines was leaking badly and at the first opportunity the bonnet was removed when it was found that not only the nut holding the disc had disappeared but the disc also, the check valves being of the renewable disc type.

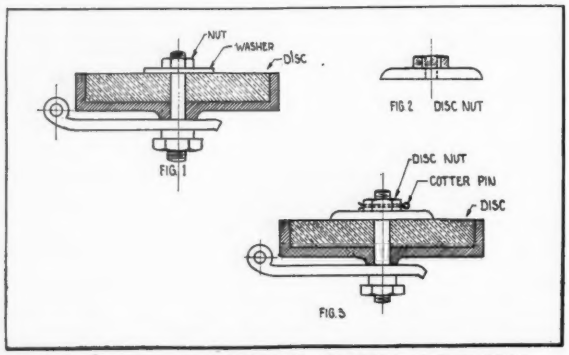


FIG. 1. NUT AND WASHER HOLDING VALVE DISC
FIG. 2. FORM OF NUT USED BY MANUFACTURER
FIG. 3. COTTER PIN PREVENTS LOOSENING OF UNIT

As I did not have another check valve of the proper size on hand nor any repair parts for the one that was out of order I make a repair in the following way. A new disc was placed into the disc holder then to hold the disc. I first placed a flat washer over the stud next to the disc then screwed a common hexagonal nut over the stud next to the washer. The nut had to be retapped to fit the thread on the disc holding stud. The idea is shown in Fig. 1 while Fig. 2 shows the type of disc holding nut used in this type of check valve.

The check valves I use on my boiler feed lines, etc., are all of the renewable type and after the foregoing experience I had a number of other disc holding nuts to come loose and get lost. They would come loose and work off the stud in spite of placing a few center punch marks at the nut and stud threads. To overcome this trouble I drilled two holes through the nut and stud holding the disc then placed a small cotter pin through one hole. After this I had no more trouble with the nuts coming loose and being lost.

I drilled two holes in the nut and stud because of the fact that, in renewing a disc, if one hole will not fit, one of the others will. The idea is illustrated in Fig. 3.

Milwaukee, Wis. H. A. JAHNKE.

Corrosion of Boiler Surfaces

ON PAGE 302 of the March 1 issue, W. H. E. gives an interesting account of some of the things which enter into boiler corrosion. May I add a little to what he has said?

Many coals, particularly some of those mined in Illinois, have a rather high sulphur content. This is frequently running as high as 3 or 4 per cent. Sulphur has an intense affinity for oxygen and in the process of combustion, it combines with oxygen in several different proportions. It may combine one part of oxygen and one of sulphur (SO) or two parts of oxygen and one of sulphur (SO_2) or three parts of oxygen and one of sulphur (SO_3). As I understand it, none of these combinations are injurious to the boiler metal.

If hydrogen is present in the fuel, as it frequently is, in the process of combustion water is formed as superheated steam. It would seem that this could combine with the sulphur trioxide producing sulphuric acid, and perhaps it does, but in my experience, I have never seen any corrosion which I thought was caused in this way; however, a slight leak in the boiler, such as a leaky tube end or a handhole plate when exposed to the products of combustion, does at once produce a serious corrosion and one that may be difficult to detect until much damage has been done.

In many cases the difficulty of detection seems to be due to the fact that the corroded spot may be fairly large and may taper off so evenly at the edges as to be hardly noticeable. Then, of course, the very location of the trouble is another factor in the difficulty of finding it.

With some types of boilers, this trouble is so serious as to prevent the use of coal high in sulphur.

Omaha, Nebr. A. G. KNIGHT.

Crankpin Knocks

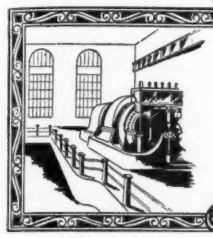
RECENTLY A large Corliss engine in a manufacturing plant developed a knock which seemed to come from the main bearing. This was taken up as much as was possible, without any improvement. An indicator was next applied and diagrams taken. Compression was increased and diminished with still no change in the knock. The crankpin was then suspected of being loose. This was closely watched, and a few days afterward the engineer noticed the crankpin oiler running considerably out of true. The engine was shut down, the connecting rod was taken off and pin inspected. It was found to be loose in the crank.

Preparations were immediately made to put in a new pin. The old one had been pressed in and the end riveted; when the rivet head was cut off, the pin was driven out of the crank with a sledge.

Another case of a loose crankpin, which did *not* knock happened in a nearby town, and in this case the crankpin oiler, of the centrifugal type, ran out of true. It was centered and tightened but a short time afterwards was again found out of true.

As the crankpin was suspected of being loose the connecting rod was taken down. The crankpin was found to have rotated in the crankpin bore about 30 deg. When struck a blow with a sledge (the pin being protected by a piece of copper) there was a vibration. A new pin was then made and put in service.

This engine had a 24-in. bore and was well loaded and it seems strange that the loose crankpin had given no notice by knocking but had, contrary to expectations, run quiet and cool. TOM JONES.



QUESTIONS AND ANSWERS

Economy of Exhaust Heater

In reply to the question of W. T. in the March 1 issue regarding the economy of a heater installed between low pressure cylinder and condenser, I would suggest that the engine be indicated with the feed water heater in and out of operation.

General practice tends to show that a condenser vacuum of more than 24 or 25 in. does not effect a compensating increase in the economy of the average reciprocating engine. The rate of decrease of steam consumption begins to fall off quite rapidly after a vacuum of about 23 in. is obtained.

With proper design of low pressure cylinder, ports and passages, there is no reason why the economy should not increase with higher vacuum. Latest practice shows the truth of this statement.

With the type of engine W. T. is operating decreasing the vacuum from 26 to 23 in. probably reduces the economy about 0.6 lb. per hp.-hr., or about 4 per cent. This must be charged up against the increased feed water temperature.

Chicago, Ill. Raymond J. Pask.

What Caused the Uneven Wear?

Referring to Tom Jones' question concerning uneven wear on piston rings on page 305, of the March 1 issue, I presume that the action was caused by a foreign piece wedging itself under one end of the ring. Perhaps there was in the piston a dull pin which might have been loose and was pushed in the hole sufficiently to let a side of the ring work itself over it, or the ring might have been step cut and one end piece broke off and slid under the ring. The uneven wear was caused by excessive pressure resulting from some hard piece which forced that part of the ring against the cylinder walls. The wear must have been gradual and caused after the piston was in place, otherwise it would have been impossible for the ring and piston to enter the cylinder if it had happened outside.

Pahrump, Nev. Chas. Labbe.

Application of Steam Traps

In looking over Power Plant Engineering for Feb. 1, I read the inquiry by W. J. M., "Are Traps Applicable Here?" As I have had a similar experience my solution may be of service to him. In the plant where I am now employed, they were, when I first came here to work, dumping water from the heating coils of three large kilns, direct into the lake. After a while, I convinced the management that all this hot water going to the lake was a large waste of money. After a while I got him to let me buy a return trap and direct this hot water (about 5000 lb. per hr.) back to the boilers.

First I put the traps at the kilns in first-class order, then piped the hot water back to the boiler room (about 450 ft.) into a tilting trap, and returned the water direct to the boilers at 275 deg. F. with little, if any, attention to the trap except to packing on valve stems possibly once a year and occasionally a little oil on the levers where they rub. Our tilting trap is about 5 ft. above the boilers and gives excellent service day and night, year in and year out. The only change I would make, if I were to install another outfit like this, would be to buy a tilting trap without outside levers or valves.

Then again I had the same trouble as he did in taking care of the condensate from a large heating plant. In his case 4 lb. is not enough to make his trap work, as the resistance is greater than his steam pressure. I installed a vacuum pump at the lowest point where condensate collected and pumped it direct into the discharge pipe that ran back to the tilting trap in the boiler room from the traps at the dry kilns.

It might be in W. J. M.'s case that 4 lb. is not enough to drive his pump; in that case, he will have to run a steam line to his pump so that he can get pressure enough to drive his pump. I think that, if he will follow these directions, his trouble will be at an end.

Seattle, Wash. J. C. Paul.

Referring to the trapping problem submitted by W. J. M. in the Feb. 1 issue, and M. A .S.'s reply regarding the pumps, if return traps were to be used, one boiler return would have to be installed 5 to 10 ft. above the boiler and a lifting or pumping trap installed in the paper mill. A high pressure steam connection would have to be made to the lifting trap in the paper mill and sufficient pressure and volume of steam available to force the condensation either hot or cold, through the 800 ft. of pipe besides the required lift of about 35 ft.

If the amount of condensation from the office, store house and hospital is enough to warrant the expense of saving it, a lifting or pumping trap with a high pressure steam connection may be installed to take the condensation from the return line in the basement at the sewer, and lift it into the hot well.

This trap or any trap on this line would tend to create a dead end and if there were any unequalization of steam pressure in any of the radiators that would hold the water back, a radiator trap would have to be installed on each radiator, allowing the condensation to flow by gravity to the lifting trap which should be vented to the atmosphere.

Cleveland, Ohio. H. F. Wood.

Forced Draft Fan or Higher Stack

With reference to the letter by F. S. in the February 1 issue, the writer does not give the diameter of the stack nor the number of hours a day during which 5 T. of coal are burned. It may be set down, however, as a fairly safe generalization that increasing the height of the stack from 30 ft. to 70 ft. will give him about 50 per cent more capac-

ity than he can get with the lesser height, whereas by putting a turbine undergrate blower under the grate he would be able to get anywhere from 75 to 100 per cent increase, so from that point of view alone it would be well worth his while to consider the installation of a blower.

In the April 1 issue G. H. Kimball comments on the above-mentioned letter and in his first paragraph his experience corroborates the statements made above. Unfortunately, in the second paragraph of his letter, in which a statement is made which is rather qualifying in its nature, there is an error of omission (probably a typographical one) in that the number of 300-hp. boilers which he had on the stack mentioned is not given. It is impossible, therefore, to discuss this phase of the situation as Mr. Kimball has outlined. A stack 3 ft. 8 in. square by 100 ft. high would, according to Kent's rating, be rated at about 350 hp., and it is possible frequently to develop as much as twice this with undergrate blower draft. From this it might appear that Mr. Kimball has two 300-hp. boilers, for operating these two units at 125 per cent of rating would give just about the maximum capacity of this stack with forced draft. The fact that it is possible to develop as much as twice the nominal rating with the stack with forced draft, is, we should say, an excellent argument for the installation of undergrate blowers.

New York City. V. H. CARPLES.

What Caused the Sudden Pressure Drop?

WHILE USING the bottom blow to freshen up a boiler the other day, the main steam line strainer stopped up with scale. The stoppage was not gradual as is generally the case but the pressure on the first stage of the turbine dropped simultaneously with the opening of the blow. The plant in question was on a ship. The steam strainer was of the basket type and the housing for it was part of the main throttle casting.

This plant had been idle for, I believe, about 2 yr. before our experience with it and the superheaters were rusted up considerably on the inside. Owing to the fact that things had to be put in order rapidly, it was possible to turbine out only the lower generating tubes and no doubt the upper rows were pretty bad. The steam drums, however, were all clean and everything else was gone over in the customary manner. As far as the density of the water in the boiler was concerned, that varied and needless to say, we were endeavoring to keep it as low as possible by blowing, so whenever it got over 100 gr. per gal., it was time to "freshen up." The engine speed was kept constant all the time, so that had nothing to do with it.

As near as I can figure it out, the vibration caused by the boiler water being blown into the sea loosened up some of the scale in the superheater and main steam line and it was carried through into the steam strainer. Just why it should be carried over so rapidly and in such quantities is hard to understand; however, it was, and I can vouch that there certainly was some quantity of scale in the strainer. It generally took about four blowing-downs of the boiler to drop the throttle pressure from the normal (full speed) pressure of 198 lb. to 80 or 90 lb.

Other engineers may have had the same thing happen to them but it was my first experience of the kind and I fail yet to see why the bottom blow would cause scale to dislodge. I had used the surface blow on the same boiler several times but the bottom one seemed to do the most damage. J. U. M.

While it is probable that vibration loosened much of the scale in the superheater and pipe lines, it is no doubt true that expansion and contraction of those parts of the system caused much of the scale to loosen, thus the process of loosening up part of the scale may have extended over a much longer time than that required for blowing down. Under normal operating conditions only a small portion of this scale reached the strainer because the steam velocities were not high enough to move the scale rapidly.

When the bottom blowdown was used there resulted a drop in boiler pressure and at the same time the engine speed was maintained constant. This resulted in an increased cut-off, in other words a larger volume of lower pressure steam was required than had been required at the higher pressure.

Passage of this greater volume of steam through the superheater and the piping system resulted in higher velocities which evidently were sufficiently high to pick up large quantities of this scale and carry it to the strainer.

Faulty Drier Operation; Steam Consumption of Drier

IN THE question submitted by M. W. C. in the Feb. 15 issue, I believe the trouble experienced is due to a difference in steam pressure in the driers or machines. Often two or more driers or machines are connected into one trap with the thought that the steam pressure is the same in each drier.

There are but few cases where the pressure is the same. If one drier is doing more work or condensing more steam than the others, the pressure at the end of the coil will be less than that of the other driers and the condensation will be held in the coil until it reaches head sufficient to overcome the difference in pressure. A steam trap placed on each drier or machine will eliminate all the trouble and increase the output of each machine. At the pressure used, the traps will discharge the condensation back to the heater. The reason that this trouble was not experienced with the boiler return trap was probably due to the fact that the boiler return trap was vented to the atmosphere.

Referring to M. D.'s problem in the Feb. 15 issue, the most accurate way to find what the steam for the drier costs would be to discharge the condensate from the trap into a barrel so that it could be weighed. The discharge pipe from the trap would have to be submerged in cold water to condense any vapors or steam that may flash off when the hot water is discharged to the atmosphere.

Weighing all the condensation for two or three days would produce more accurate results than to try to figure the amount of steam being condensed by the radiation on a condition of this kind.

Cleveland, Ohio. H. F. WOOD.

Condensate Return Lines

G. S.'s HEATING system as described on page 305 of the March 1 issue will work provided there is sufficient steam pressure escaping through the return traps to overcome the friction of the return pipe lines and to force the water back to the boiler feed pump. Air pockets must be eliminated in the return lines and it may be necessary to put air vents on the ends of each radiator coil to allow

the air to escape and prevent air binding as is common with some high pressure heating systems.

It appears, however, that the receiver at the feed pump is too small for storing the condensate from 20,000 ft. of radiation and some provision should be made to store this hot return water. At times when the steam is first turned on, the boilers could not use the entire volume as fast as it came back while in an hour or so, when the coils became thoroughly warm there would not be sufficient return condensate to supply the boilers with feed water and some of the condensate stored in a tank or hot well could be used as makeup water. Being warm it would save enough in fuel to pay for the installation of the tank or hot well.

If it is necessary to carry 30-lb. steam pressure in order to gain the required temperature in the drier room, this gravity return system may prove the best but for my choice I prefer to carry a lower steam pressure if possible and use a vacuum return system which would allow the use of smaller return pipe lines and eliminate much of the trouble of steam binding of the boiler feed pump when the return condensate comes back too hot. A vacuum return pump could be connected to the return pipe to insure better circulation with less steam pressure. A small spray jet in the strainer near the vacuum pump would condense the steam when the condensate came back too hot. With this arrangement the system could be operated on the gravity principle in case anything happened to the vacuum pump.

Care must be used in selecting the kind of radiator return trap to use with both a vacuum and gravity return system. Some which give good results on a vacuum system will not work at all on a pressure gravity heating system without changing the adjustment to accommodate the greater expansion due to the higher steam pressure and back again for the vacuum system. A radiator return trap should be selected which will, as far as possible, divide these two extremes to give best results without having to be readjusted each time a change is made in method of operation.

Cambridge, Mass. R. A. CULTRA.

Secondary Air to Complete Combustion

IN THE Feb. 1 issue, on page 203, H. C. R. asks for information in regard to admitting cold air through the bridge wall from a point below the grate into the combustion space back to the bridge wall to complete combustion and if the chilling effects of the air will be offset by more complete combustion.

It is generally considered that the admission of cold air beyond the bridge wall is too late to serve combustion for any gain in economy unless a secondary arch be built partly around the circumference of the boiler and extend down to a point about in line with the top of the bridgewall, to prevent the unburnt gases from striking the comparatively cool boiler, which would tend to produce more smoke. As the installation of such arches has caused the shell of horizontal tubular boilers to become overheated, I do not recommend its use.

I do not think his troubles are caused by lack of air but rather by the incomplete application of air. In burning bituminous coals, we must have a reasonable amount of excess air, at the right time and at the right place, otherwise we may have a large quantity of black smoke in the presence of a great excess of air.

Installing a damper in the furnace door so as to admit a portion of air over the fire may help to some extent but before making any mechanical changes with the boiler, I would observe the condition of the draft with varying thickness of the fuel bed, study the temperature of the escaping flue gases, and with the aid of an Orsat, the CO_2. The losses in the boiler setting can then be determined and it is only a matter of experimenting to get a better application of air.

New Bedford, Mass. R. G. SPOONER.

Corliss Valve Setting

WILL YOU kindly give me full instructions on setting the valves on a single eccentric Corliss engine?

V. A. E.

A. Remove the steam and exhaust bonnets; the end of each valve will be found a mark corresponding to the opening edge of the port. The direction of motion for opening the valve can be determined by working the wristplate by hand. Examine the wristplate hub and bracket. On the bracket will be found a mark corresponding to the central position of the wristplate and two others locating the extreme travel of the wristplate in either direction.

See that the rocker arm travels an equal distance each side of the vertical position. To do this, loosen the eccentric and rotate it slowly about the shaft. With a plumb bob and scale measure the distance the rocker arm travels each side of its central position, adjust the length of the eccentric rod to make the distances equal. Rotate the eccentric about the shaft and ascertain whether or not the wristplate travels an equal distance each side of its central position, as shown by the travel marks. If it does not, adjust the length of the hook rod to make the travel equal.

Block the wristplate in its central position then pull up the dashpot rods until the hook pins engage with the steam hooks. Adjust the length of the steam and exhaust radius rods until the valves have the proper amount of lap as determined by the size and speed of engine. Throw the wristplate with the starting bar first to one, then to the other extreme position, and adjust carefully the length of the dashpot rods so that the steam hooks will latch with the hook pins when the wristplate is at its extreme travel, allowing about $\frac{1}{32}$ in. for clearance.

Place the engine on dead center and see that the hook rod is fastened to the wristplate. Turn the eccentric in the direction of rotation until the proper amount of lead is secured then fasten the eccentric in that position. Turn the engine to the opposite dead center and measure the lead. If it is not the same, make it so by adjusting the length of the steam radius rods.

Block the governor in the normal running position and fasten the reach rod levers at right angles to a line drawn half way between the two rods, then adjust the length of the reach rods until the knockoff arm stands vertical. With the governor in this position, turn the engine over until cut off occurs and measure carefully the distance the crosshead has traveled then place the engine in the corresponding position on the other stroke and adjust the length of the reach rod until the cutoff will just take place. This insures equal cut off at each end of the cylinder for this position of the governor. See that the governor dash pot is properly adjusted and that the pot is filled with light oil.

Drop the governor to its lowest position and see that safety blocks on the knockoff cams are adjusted so as to prevent the steam hooks from latching with the hook pins.

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Problems in Boiler Furnace Design

A few years ago, before the prefix "super" had acquired the looseness of application it has today, it was a comparatively easy matter for an engineer versed in combustion to design a furnace for a particular boiler with reasonable assurance that the job, when completed, would be a success. Practice was, more or less, standard and he was in possession of certain facts and numerical data which enabled him to proceed on the design of any furnace with confidence.

Today the entire situation has changed. We are dealing with super-power, super-boilers, super-furnaces, etc. New developments are following each other with such rapidity that it takes all of one's time to keep abreast of them. Standard practice in furnace design is concealed behind a curtain of new theories and applications of these theories and every new station that is constructed has something new to offer. This is encouraging and is as it should be, for it is only due to such pioneer work as is being done today that continued progress in the field can be assured.

High capacities, high ratings, changes in boiler and stoker design, new fuels, heat balance considerations, etc., are all factors which the furnace designer of today has to cope with and with so many variables it is not to be wondered at that there should be a diversity of opinion and a large variety of new designs.

The problem in modern furnace design is to produce a furnace which, when operated in conjunction with other apparatus in the plant, will, while maintaining the required continuity of service, produce the largest number of salable kilowatt-hours at the lowest cost when fixed and operating charges are considered.

For some time past, combustion engineers have been agreed that it is advisable to supply to the furnace a certain amount of low level heat derived from sources where it would otherwise be wasted, or used at extremely low efficiency. By thus reclaiming this heat and delivering it to the furnace, it is apparent that a thermal gain would result. While this is entirely satisfactory from a theoretical standpoint, there are practical difficulties in the way which it is the furnace designer's business to overcome.

Again, where powdered fuel or oil is used, it has been practice to use air-cooled walls in which the air for combustion is preheated. The furnace walls are, at the same time, kept cool due to this heat exchange. While this system is in use in a number of plants, other engineers do not agree that this is advisable. They contend that it is not good practice, first, because it is uneconomical to allow high head heat (which should be used only for converting water into steam) to be used for air preheating when there is so much low head heat readily available; secondly, because (they claim) furnace maintenance will be high, due to the extreme differences in temperature between the inner and outer surfaces of the furnace walls.

For the preheating of air for boiler furnaces with low level heat, two methods have been proposed, one using the heat of the waste gases in the stack and another in which steam bled from the lower stages of the turbine is used to heat air to the furnace. The former has been used with some success. The latter is a novel scheme and shows considerable thermal gain although its use will require further development in heat exchanging equipment.

From even these few considerations it must be obvious that the problems confronting the furnace designer today are somewhat complicated. In an article appearing in this issue, Edwin B. Ricketts discusses the present status of

furnace design in greater detail. He presents modern developments in furnace design in an impartial manner and the reader who wishes to obtain more information on this subject will find much of interest in this article.

Evaporators Lengthen Period of Continuous Boiler Operation

At best the raw water available for feeding boilers is a long way from being chemically pure. Most waters contain scale forming impurities; some river waters in addition to carbonates and sulphates contain enough free acid to do material damage to boiler metals; many soluble salts also add their quota of trouble. These impurities have been a serious hindrance to the efficient operation of power plants due not only to the insulating effect of the scale formed but also to difficulty in the use of steam of high pressure and temperature. In many cases they prevent working the boilers at a load which would otherwise give better economy.

Since the time boilers were first used to generate steam for commercial purposes, engineers have resorted to every conceivable means for preventing formation of scale in boilers and corrosion of the metal. Scientific chemical treatment has given the nearest approach to a universal solution to the problem but even the most perfected chemical treatment does not offer a complete solution.

Of late years considerable attention has been given to the use of evaporators for distilling make-up water feed to the boilers and the success with which they have been applied merits further investigation into their field of application in power plants. Obviously, it would be uneconomical to use evaporators in plants where there is little or no condensate returned; in fact they are seldom considered except in cases where the make-up requirements are as low as 15 or 10 per cent. Thermally, the evaporator has a high efficiency, the loss, when the installation is properly designed, being only that due to blow-down and radiation. Blow-down may be small or a considerable amount, depending upon the purity of the water fed to the evaporator. Radiation is a small item when the apparatus is properly insulated. Some power is required for circulating the water in some types of evaporators and this must be taken into consideration.

Not long ago it was the practice, even in plants using treated water, to take the boilers out of service for internal cleaning one every month or six weeks. Evaporators have made it possible to lengthen this period of operation to one year without the risk of scale formation. This alone is a great saving to the plant.

Several makes of evaporators are described in an article in this issue; in subsequent issues of Power Plant Engineering, a series of articles dealing with heat balance problems in plants where evaporators are installed will be published. Each plant presents individual problems with which the engineer should familiarize himself.

Do You Carry Job Insurance?

Clanging fire bells, a sound of scurrying feet, a red glow against the blackness of the night and our thoughts turn to fire insurance policies. The funeral cortege winds its solemn way toward the city's edge and our minds dwell on the need for providing for our loved ones when such a time may come. But when the boss with sober face explains that owing to the unusual conditions confronting the company, our services will no longer be required—what then?

If you are wise you are carrying job insurance. It doesn't go by that name and you may say that there "ain't no such animal," but there is.

When you buy your engineering books, pay your dues for professional societies or renew your subscriptions for the technical and industrial papers you are taking, you are paying your premiums on job insurance. It may not be quite so definite an arrangement as the fire or life insurance but the idea is the same.

All of the agencies you make use of to increase your own knowledge, to make yourself more valuable to your employer and a greater credit to your trade or profession, increase the probability that your income will not only continue, but will increase with passing years. It is true that you may be out for a time but the insurance works and back you come, to another and possibly better job.

Every professional man owes it to himself and to the profession which he represents, to set aside a definite portion of his income for his own professional advancement. This statement is not our own but is a recollection of one made by Roosevelt. It is good advice and might be summed up with the question: Do you carry job insurance?

Selecting Centrifugal Pumps

Considered from a purely mechanical point of view a centrifugal pump does not appear to be an unusually intricate piece of apparatus. Consisting mainly of a casing together with a runner or impellor mounted on a shaft, it might seem that one centrifugal pump was as good as another for a particular purpose, in spite of the fact that the curvature of the vanes and passageways differ slightly.

In reaching this conclusion, however, the casual observer would be greatly mistaken. The slight variation in the curvature of the component parts of a centrifugal pump often make all the difference in the world so far as the pump's performance is concerned.

Now, performance is just what the buyer of a pump is interested in and, if he has to select a pump for a certain purpose, he must have some means at hand whereby he may learn something of the pump's performance under various conditions. Obviously, it is impossible for him to determine this from an examination of the constructional features. How then is he going to determine it?

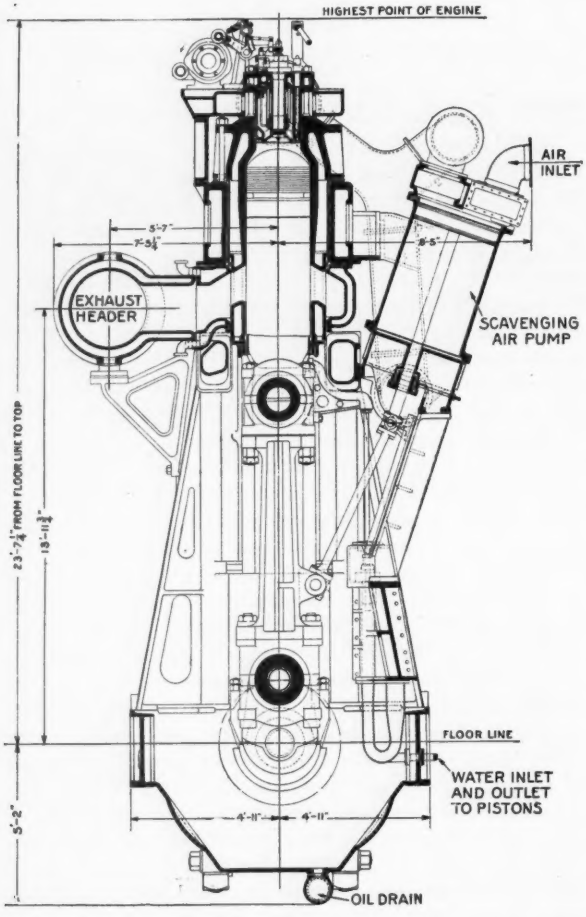
It is here that the characteristic curves supplied by pump manufacturers come to his aid. These curves, usually showing head, power, capacity and efficiency, when plotted together provide a complete graphic record of the pump performance under nearly all conditions. If any one of these four items is known, the other three can be determined directly from the characteristic curves without further calculation. In modern practice where it is more often necessary to adapt the pump to the speed of the driving unit which is more or less fixed and unalterable, than to suit the motor speed to that of the pump, these characteristic curves are of particular value. They enable a pump to be selected which will operate at its highest efficiency when running at the normal speed of the driving motor.

In an article appearing in this issue, the uses of pump characteristics are discussed in detail and it is hoped that the information contained therein may be of value to those having occasion to purchase or to recommend the purchase of centrifugal pumps.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

Diesel Engine Constructed Without Cylinder Heads

IMPORTANT features of the new Bethlehem oil engine are illustrated in the accompanying drawing. It is of the full Diesel, vertical, two-stroke cycle, single-acting type, constructed in units of four, six, or eight cylinders.



SECTIONAL ELEVATION OF THE BETHLEHEM TWO-STROKE-CYCLE DIESEL ENGINE

It is designed to run at a speed of from 116 r.p.m. for land power and twin-screw marine purposes down to 90 r.p.m. for single-screw marine use. The basic idea was to design an engine in which all parts subject to flame temperatures would be so designed as to be able to resist successfully the combination of temperature and pressure stresses inseparable from the operation of oil engines under heavy load.

To accomplish this object the power cylinder is designed with an inner and outer cylinder wall which is united only at the top and at a point removed from the heat of combustion. Further, the power cylinder is contracted at the top from cylinder bore to the diameter of the valve cage so that there is no separate cylinder head. In internal combustion engines the inner cylinder wall is subjected to flame temperature inside and water temperature outside and the outer cylinder wall is subjected to water temperature on the inside and engine room temperature on the outside. Therefore, it is evident that differential expansion between inner and outer walls must inevitably occur. The construction of the Bethlehem engine is planned to avoid trouble from this source.

Exhaust ports are cast integrally with the cylinder barrel, thus avoiding any joint between cylinder barrel and exhaust ports. Such a joint, if present, would have to hold hot gases on one side and water on the other. In using fuels high in sulphur, this element will also be present in the engine exhaust and the slightest water leak through such a joint would produce troublesome corrosion. Studs passing through the two upper cylinder flanges hold the cylinder to its support. The combustion pressure in any power cylinder is exerted downwardly on the piston and upwardly on the cylinder. In the construction of this engine the upward pressure passes directly to the cylinder flanges and studs and so to the cylinder support, which is held down to A frames and the bed-plate.

At the upper end of the cylinder a large amount of heat must pass to the water jacket in a short space of time. The greater the wall thicknesses, the greater the consequent difference between the temperatures of inside and outside surface of cylinder walls. The greater such difference in temperature, the quicker a cylinder will fail, due to heat fatigue.

Thickness of the cylinder wall is uniform in that portion of the cylinder subject to maximum temperature and pressure, the wall thickness decreasing with the lower pressures in lower part of cylinder. Scavenging air enters through a mushroom shaped scavenging valve. The shape of the cylinder is so designed that the incoming current of scavenging air passes directly along the heated wall surface, thus absorbing from it some of the heat in addition to that passing to the water jacket. Pistons, inlet cages and fuel valves are water-cooled, while the scavenging valve is positively cooled by the incoming scavenging air. All working parts, except the piston, necessary for the operation of a power cylinder, viz: fuel valve, scavenging valve, air starting valves and relief valve, are contained in a single compact and easily removable cage.

When the engine is erected, long bolts extending from the top of the cylinder down through the bedplate are tightened so as to produce an initial tension in the bolts about 25 per cent greater than the maximum tension arising from combustion pressure in the cylinder. The bolts are of such a size that this initial tension is not more than 20 per cent of the elastic limit of the material. Since the initial tension in these bolts is more than the maximum tension due to combustion pressure, it follows that the bolts do not stretch while the engine is working. The A frames are always in compression.

Perfect combustion in any oil engine requires that the power cylinders be efficiently cleared of exhaust gas. In the Bethlehem two-cycle engine the scavenging air enters through a central scavenging valve in the extreme upper end of the cylinder, forming an axial column which entirely fills the power cylinder and drives before it the burnt gas, which escapes through exhaust ports located around the entire circumference of the lower end of the power cylinder.

Injection air is supplied by a three-stage air compressor driven from a special crank on one end of the crank shaft. Fuel valve lift control permits the lift of all fuel valves to be quickly regulated from zero to full lift. A simple device is furnished with the engine for removing pistons from the bottom of the cylinders without disturbing any of the valve gear or piping on top of the engine.

Scavenging compressors are arranged on an incline and are driven from the main connecting rods. After 15 mo. continuous operation it is impossible to detect any more evidence of wear on the lower side of the scavenging cylinder than on the upper side. Since the total forces due to one scavenging compressor are less than two per cent of those passing through the main connecting rod by which the compressor is driven, it is evident that no more wear will be found on this main crankpin than on the others.

To show the reliability of this oil engine, which is a product of the Bethlehem Steel Co., a 30-day continuous endurance run was made with the six-cylinder engine now being regularly used to generate alternating current for steel mill service in the Bethlehem plant. The following data gives the average results of the test:

1.	Duration	730 hr., 35 min.
2.	Total revolutions	5,057,997
3.	Average r.p.m.	115.3
4.	Total kw-hr. produced	1,211,900
5.	Average kw. load	1,659
6.	Average b.hp.	2,522
7.	Average i.hp.	3,582
8.	Average mech. efficiency per cent	70.4
9.	Total pounds fuel oil consumed	849,829
10.	Average pounds fuel oil per kw.-hr.	0.70
11.	Average pounds fuel oil per b.hp.-hr.	0.46
12.	Total gallons bearing oil consumed	716.0
13.	Total gallons cylinder oil consumed	189.5
14.	Total pounds cup grease consumed	158.5
15.	Average gallons bearing oil per hr.	0.98
16.	Average gallons cylinder oil per hr.	0.25
17.	Average total gallons lubricating oil per hr.	1.23
18.	Equivalent sea mileage of total revolutions	8,700

Note: Ordinary plant fuel oil was used, varying from 22 deg. to 30 deg. Baumé with high sulphur content.

CO_2 Recorder Registers Once Every Three Minutes

MOTOR OPERATED, no running water piped to the machine and simplicity of operation are three features of the Defender Automatic Regulator Co.'s CO_2 Recorder.

This instrument is of the single pen type which records on a round chart the per cent of CO_2 present in the flue gas. The chart is also marked to show the per cent of excess air used, the per cent of preventable fuel loss at a flue gas temperature of 580 deg. F. and the pounds of air used per pound of fuel fired.

Construction of the instrument case is of metal which is black japanned. The top and bottom members of the case are of cast iron and the door, which is also made of metal, is in one piece. The caustic potash tank is made of cast iron without flanges or gaskets. The three water tanks are made of copper and leaded on the inside. The float is also made of copper and is leaded on the outside.

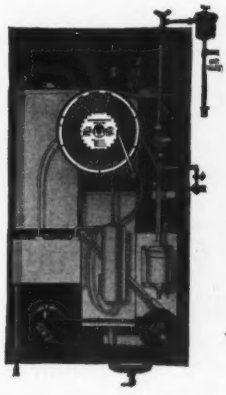


FIG. 1. DEFENDER CO_2 RECORDER WITH FRONT COVER REMOVED

FIG. 2. ORSAT APPARATUS MAY BE HUNG ON RECORDER TO CHECK KOH SOLUTION

No running water flows to the machine, therefore, drain pipes are not necessary. Outside dimensions of the case are 30 in. high by 16½ in. wide by 9 in. thick and the weight of the complete machine is about 90 lb.

Ordinarily the machine is set to take a reading every 3 min.; this interval, however, can be increased or decreased by means of a simple adjusting screw device. Ordinarily the motor operates 1 min. out of every three, the motor being in operation while the gas is being drawn from the boiler setting.

In Fig. 1 is shown an interior view of this machine with a gas filter mounted on top at the right. The gas is drawn from the boiler and up through the filter to remove the soot. Below the filter is fitted a short length of 8-in. pipe with a drain cock at the bottom. This pipe serves to remove the moisture which may be present in the flue gases.

To place the machine in operation, the two lower tanks are first filled with 3 gal. of water, that is, until the water runs out at an overflow provided in the center tank. The two bottom tanks are connected together at the bottom with a U tube. The lower right-hand tank is sealed at the top and connected to the gas line with ⅛-in. piping. This

piping contains a three-way cock. A small motor in the lower part of the case drives a small centrifugal pump. When this motor is started by turning on the switch, the water is pumped out of the two lower tanks into the top or left-hand tank. As the water is pumped out of the lower tanks the gas from the boiler is drawn into the lower right-hand tank. This tank holds enough gas to clean 180 ft. of ¼-in. pipe, consequently, there is no lag.

When all the water has been pumped out of the lower tanks, a float in the upper left-hand tank reaches the top and throws out the switch which stops the motor. The water will now start to run back by gravity into the tanks in which it was stored originally.

At the same time that the float throws the motor switch, it also turns the three-way plug in the gas line, shutting off the gas supply from the boiler and opening an exhaust. The water then flows back by gravity from the top to the lower tanks and a small trap shown on the front of the lower right-hand tank traps a sample of gas and forces it over into the KOH tank where the CO_2 is absorbed out of the gas. The remainder of the gas passes into the center bell which causes it to raise and operate the pen arm. As the water recedes and finds its level in the three tanks, the float again throws in the switch which starts the motor and at the same time opens the plug cock on the gas line so that another cycle of the machine takes place.

Provision is made on the front of each case to hang an Orsat apparatus which should be used to check the strength of the KOH solution.

Kansas Power Companies Combine

A MERGER of numerous public utility properties in Kansas under the control of one company to be known as the Kansas Public Service Co., with assets of more than $13,000,000, was brought about recently. The Kansas Power and Light Co. has also been formed to build the new power plant at Tecumseh and transmission lines in Kansas, among them the line from Topeka to Atchison. Permission to organize the new company was recently granted by the Charter Board of Kansas.

Merger of the properties, officials pointed out, is another forward step in the program of public utility development in the Central States which has been mapped out by the Illinois Power and Light Corporation now operating in more than 350 cities and towns of five states in the Mississippi valley. The formation of the new companies was effected around the Topeka Railway and Light Company, which was the holding company and owned all the stock of Topeka Edison Company and the Topeka Railway Company. The Illinois Power and Light Corporation owned all of the stock of the Topeka Railway & Light Co., also the Atchison Railway Light & Power Co. and the Wichita Railway & Light Co.

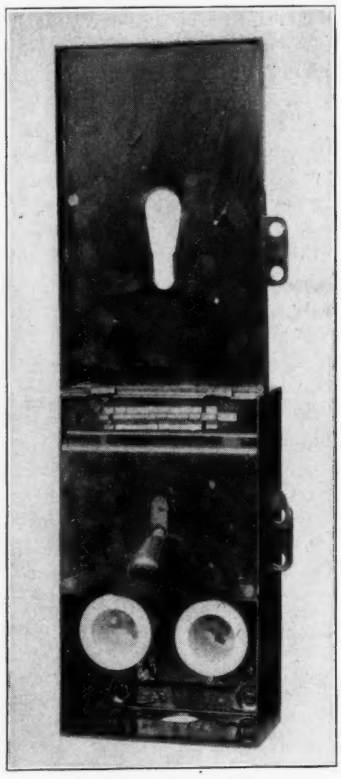
Under the new arrangement the Topeka Railway & Light Co. changes its name to the Kansas Public Service Co. and takes title to the property of the Atchison Railway, Light & Power Co. and the Wichita Railway & Light Co. It will as formerly own all the stock of the Topeka Edison Co. and the Topeka Railway Co., and in addition purchase all the common stock of the Kansas Power & Light Co.

Officers of the Kansas Public Service Co. are Clement Studebaker, Jr., president; William A. Baehr, H. L. Hanley, vice-presidents; Scott Brown, vice-president and secretary; George M. Mattis, treasurer, and Edward Woodman, clerk.

Directors are Clement Studebaker, Jr., William A. Baehr, H. L. Hanley, Scott Brown, John W. Esmond, P. C. Dings and George M. Mattis.

New Starting Switch Protects Small Motors

FOR USE with small alternating current motors, the General Electric Co. has developed a new single-throw starting switch known as the CR-1038-A1. This switch is of the three-pole type, designed for quick "make and break," and is operated by an up-and-down movement of the handle. The unit is compact and of substantial construction to permit of wall or pedestal mounting.



NEW G. E. MOTOR STARTING SWITCH WITH COVER OPEN

Overload protection is provided by means of two thermal cutouts, one connected in each of two legs of the motor circuit, in order to protect all phases of the motor against unbalanced and single phase overloads, as well as overloads distributed over all phases. These thermal cutouts have an inverse-time characteristic and sufficient thermal capacity to permit the motor to operate at all overloads of short duration that are not objectionable from the standpoint of overheating the motor. A new feature in the design of these cutouts is the elimination of the old screw base, two screws being used to fasten the cutout in place, the screws being readily loosened to remove the device if necessary. The fusible links may be removed without removing the cutout.

World Power Conference

PROGRAM of the Conference to be held in London, England, June 30 to July 12, by representatives of the engineering societies of 16 countries, is now in fairly definite form. The program committee for the United States is J. W. Lieb, chairman, Peter Junkersfeld and Calvert Townley. The aim of the papers presented is to show the character and extent of the power development in this country and conditions under which such development has been undertaken.

First will be a review of power resources by O. C. Merrill of the Federal Power Commission, N. C. Grover and M. R. Campbell of the Geological Survey. Regional surveys will be given by J. W. Lieb of the New York Edison Co., Samuel Insull of the Commonwealth-Edison Co., A. H. Markwart of the Pacific Gas and Electric Co., and H. A. Barre of the Southern California Edison Co.

Water Power Production will be treated by J. R. Freeman, consulting engineer, H. J. Pierce of the Washington Irrigation and Development Co. and E. C. Babb of the Federal Power Commission. High Dams will be discussed by A. P. Davis, consulting engineer, and Water Wheels by W. M. White of the Allis-Chalmers Mfg. Co. and H. B. Taylor of Wm. Cramp & Sons Ship and Engine Building Co.

Preparation and Use of Fuels will be treated in a paper by C. F. Hirshfield of the Detroit Edison Co.

In the section on Steam Power Production, papers will be presented by Peter Junkersfeld of McClellan & Junkersfeld, G. A. Orrok, consulting engineer, D. S. Jacobus of the Babcock & Wilcox Co., W. L. R. Emmet of the General Electric Co., W. S. Monroe of Sargent & Lundy and F. N. Hodgkinson of the Westinghouse Electric & Mfg. Co. These papers will cover Steam Generation, Power from Mercury Vapor, High Pressure and Superheat, and Steam Turbines and Condensing.

Electric Transmission and Distribution will be presented in three papers by B. G. Lamme of the Westinghouse Electric & Mfg. Co., F. G. Baum, consulting engineer, and W. S. Murray, consulting engineer.

Industrial Power Utilization will be considered, for the Steel Mills by B. H. Shover, consulting engineer, for the Textile Industry by C. T. Main, consulting engineer and for the Paper Industry by A. H. White of the International Paper Co. Electro-Chemical Progress will be presented by F. A. J. Fitzgerald of the Fitzgerald Laboratories and Power in Metallurgy by an author to be selected.

Power for Transportation will have two papers, one on Railroad Electrification by B. J. Arnold of the Arnold Co., the other on Electric Ship Propulsion, author not yet announced.

Concerning Economic, Financial and Legal Phases of Power Production, Herbert Hoover, Secretary of Commerce, will present a paper on Government Policies Relating to Power Development, Problems of Financing will be taken up by S. Z. Mitchell of the Electric Bond & Share Co., Power Development and Industrial and Economic Progress by G. E. Tripp of the Westinghouse Electric & Mfg. Co., International Views on Power Development by O. D. Young of the General Electric Co., Public Regulation of Public Utilities by C. D. Jackson of the National Association of Railway and Utilities Commissioners and Private vs. Public Ownership by an author to be selected.

On Relation of Power Application to Public Welfare, a general paper will be presented by Julius Barnes of the United States Chamber of Commerce, also one on New Fields for Power Application by E. W. Rice of the General Electric Co., one on Progress in International Standardization by A. E. Kennelly of Harvard University and one on Power Development and Labor by an author to be announced.

In the discussion, F. H. Shepard, W. B. Potter and L. B. Stillwell will take up Railroad Electrification and H. J. Harriman will speak on Power Development and Industrial Programs.

These papers are only those to be presented by the United States delegation and the program is subject to change and additions.

N. E. L. A. to Meet in Atlantic City

PLANS are nearing completion for the Forty-seventh Annual Convention of the National Electric Light Association which will be held at the Million Dollar Pier, Atlantic City, May 19-23, inclusive. As usual, it will include general and specialized sessions of great interest, which will broadly summarize the work of the year in the fields covered by the four National Sections of the organization: Accounting, Commercial, Public Relations, and Technical.

Of especial interest to men in the power field are the reports of the Technical National Section, including beside the Section's Executive Committee the Committees on Accident Prevention, Electrical Apparatus, Hydraulic Power, Inductive Co-ordination, Meters, Overhead Systems, Underground Systems, and, most important of all from this standpoint, the Prime Movers Committee. The reports of all these committees will be presented on Tuesday afternoon, May 20, by the respective committee chairmen, and a brief discussion of the general activities of the section will follow. The main discussion of these reports will be held on Wednesday and Thursday afternoons, May 21 and 22. Discussion in these sessions will be led by men prominent in their respective fields, with addresses by leaders and general discussion.

One of the general sessions, probably that on Wednesday morning, will hear an address which Secretary of Commerce Herbert Hoover has agreed to deliver by telephone. His subject will be the superpower conference and the progress of work in this direction.

Senator Capper of Kansas will address the Convention on Wednesday evening, dealing with a subject related to the development of use of electricity in agriculture.

A wide diversity of entertainment will be provided, one of the central features of which will be the music by Paul Whiteman's Orchestra, which will be furnished daily beginning with the dance following the President's Reception on Monday evening.

Special railway rates have been secured, by which a member with dependent members of his family can secure fare-and-a-half rate for the round trip. Western delegates and guests will be provided with special railway service from Chicago, Detroit, and Cleveland, a special De Luxe train leaving Chicago at 1 p. m. on May 18 and arriving in Atlantic City at 9:30 a. m. on the 19th.

A. I. E. E. Annual Convention at Chicago

MANY TECHNICAL FEATURES and an especially entertaining list of social sport events are on the program for the annual convention of the American Institute of Electrical Engineers at the Edgewater Beach Hotel in Chicago, June 23-27. An entire day will be devoted to the conference of the Section delegates.

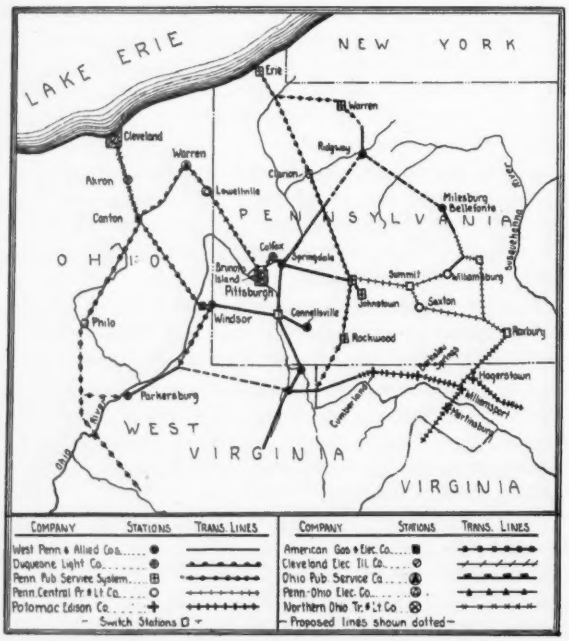
Among the technical features there will be papers on distribution, transmission, cables, reactors, automatic substations, machinery, communication, electrophysics and street lighting. A special meeting will deal with the subject of standardization from several standpoints and on one morning the Technical Committees will report on the year's progress.

Entertainment features will be particularly enjoyable. There will be an automobile trip through Chicago's excellent boulevards in addition to inspection visits to an automatic telephone exchange, and automatic substation, the Western Electric Co.'s plant at Hawthorne, the Gary steel works, the Pullman Co. and the Field Museum. A boat trip on Lake Michigan is also planned.

Golf, tennis and water sports will add to the pleasure of the meeting. Also teas and trips for the ladies are planned and there will be dancing at the hotel every afternoon and evening. On Thursday night a special fanciful entertainment will be staged.

Coal Field Systems to Be Interconnected

SOME FURTHER details are now available as to the plan for interconnecting the big central stations in the eastern coal field. The map herewith shows the present and proposed stations also the present and proposed connecting lines, covering Maryland, Pennsylvania, eastern Ohio, northern West Virginia and an outpost into Virginia. Connection is also contemplated to the Niagara district and possibly with the New England system. Many of the plants shown on the map will be recognized as notable in size and equipment. One at Springdale has several interesting features.



MAP SHOWING INTERCONNECTION POSSIBILITIES IN COAL FIELDS

The Springdale plant is located on the bank of the Allegheny River and its coal comes by under-river tunnel from mines on the other side of the river. The coal is transported, dumped, crushed, elevated and fed to the boilers by mechanical means, so that it is never handled manually from the time that it leaves the mine. Ash removal is also entirely mechanical. The installed capacity is 150,000 hp. of Westinghouse apparatus and the ultimate planned capacity is 400,000 hp.

In the area covered by the system, there is potential hydraulic power of over 1,000,000 hp., some of which is under development, while the present and proposed steam power plants connected to the system will be many times this amount. The present capacity of the steam stations is well over 2,000,000 hp.

Capacities of the stations shown are as follows:

Company Owning	Station	Total Connected Capacity of Company	Status of Station
West Penn and Allied	Parkersburg		Completed
	Windsor		Building
	Rivesville		Building
	State Line		Building
	Connellsville		Completed
	Springdale		Building
	Ridgway		Completed
	Milesburg	500,000 hp.	Completed
Duquesne Lt.	Colfax		Completed
	Brunots Id.	400,000 hp.	Completed
Penn Public Serv.	Erie		Completed
	Warren		Completed
	Seward		Completed
	Johnstown		Completed
	Rockwood	115,000 hp.	Completed
	Clarion		Building
Penn Central Power and Lt.	Williamsburg		Completed
	Saxton	60,000 hp.	Completed
Potomac Edison	Cumberland		Completed
	Berkeley		Completed
	Martinsburg		Completed
	Williamsport		Completed
	Hagerstown	50,000 hp.	Completed
Am. Gas & Elec.	Windsor		Completed
	Canton	240,000 hp.	Completed
	Philo		Building
Cleveland Elec.	Cleveland	340,000 hp.	Completed
Ohio Public Serv.	Warren	90,000 hp.	Completed
Penn-Ohio Elec.	Lowellville	60,000 hp.	Completed
N. Ohio Tr. & Lt.	Akron	90,000 hp.	Completed

TO FIND the horsepower necessary to elevate water to a given height, multiply the weight of the water elevated per minute in pounds by the height in feet, and divide the product by 33,000 (an allowance should be added for water friction, and a further allowance for loss in steam cylinder, say from 20 to 30 per cent).

Steam Produces Novel Lighting Effects

LIVE STEAM is used to produce a novel lighting effect in the illumination of the new million dollar office home of the San Joaquin Light and Power Corporation at Fresno, California. This building has attracted the attention of electrical men on the Pacific Coast because of its unusually well designed system of exterior illumination.

NEW OFFICES OF THE SAN JOAQUIN LIGHT & POWER CORP.

A night photograph of this building is shown in the accompanying illustration. This building has over 300 floodlights on the exterior and uses 45 different colored lighting schemes.

A feature of this illuminating system of particular interest to power plant engineers, as it introduces a new use for steam, are the cloud producing cauldrons installed on the promenade on the tenth floor. Live steam is piped from the basement to these huge cauldrons, where it is released into the night air, forming beautiful cloud effects. Into these clouds, colored lights are played, producing a novel display.

On top of the building is a large electric sign displaying the name San Joaquin Power. The letters in this sign are 8 ft. high and can be seen for miles.

Another feature of the new building is the heating, cooling and ventilating system. Air is washed by fresh water and purified in violet-ray machines in the basement and then re-circulated. Windows are kept closed the year round. In 24 locker and wash rooms are electric Airdry towels, using warm air and operated by individual motors. From the street to the top of the radio towers, it is 235 ft. There are a thousand lights inside the building and 250 base or floor plugs. The building was erected in fourteen months by the R. F. Felchlin Co., architects and builders; the design was executed by Raymond F. Shaw, architect of the firm, and the exterior floodlighting plans were approved by W. D'Arcy Ryan, who designed the famous Tower of Jewels lighting at the San Francisco Exposition in 1915. The elevators operate at a speed of 600 ft. a minute. On the tenth floor are the auditorium, stage, motion picture projecting room, library, cafeteria and electrically-equipped kitchen for use of the 400 employes.

Electric Power Production in U. S.

REPORTS FROM the Department of the Interior, U. S. Geological Survey, indicate that the average daily production of electricity by public-utility power plants in February exceeded all previous records of output, with a production of 168,300,000 kilowatt-hours per day.

This figure exceeds the previous record established in January by a small amount. Based on the records of output for January and February for 1922 and 1923, the production of electricity by public-utility power plants for

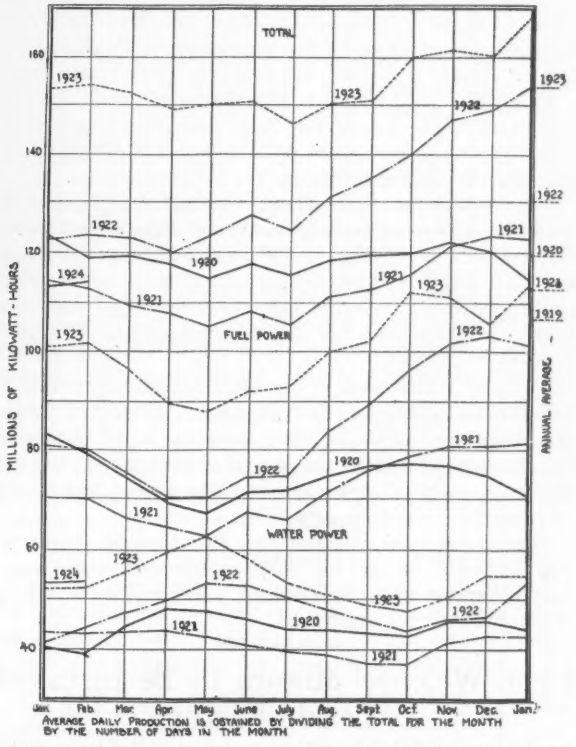


CHART SHOWING CURVES OF POWER PRODUCTION FOR PAST FOUR YEARS

1924 is apparently starting off under the same favorable conditions which produced the record outputs of production of electricity in 1922 and 1923.

In the accompanying chart are shown curves of the daily output of electricity in kilowatt-hours by public utility plants for each month for each of the last four years.

The daily production of electricity by the use of water power remained almost constant during December, January and February. About one-third of the total production of electricity in these three months was produced by the use of water power.

These curves are based upon the operation of about 4000 power plants, each producing 10,000 kw.-hr. or more

per month engaged in the production of electricity for public use, including central stations, electric railway plants, and certain other plants that contribute to the public supply. The total capacity of the generators in these plants is about 17,800,000 kw. Reports are received from plants representing over 95 per cent of the total capacity. The output of those plants which do not submit reports is estimated; therefore the figures of output and fuel consumption as reported in the accompanying tables are on a 100 per cent basis.

Westinghouse Sharon Plant Extended

SEVERAL new buildings and additions to the Sharon Plant of the Westinghouse Electric & Mfg. Co. located in Sharon, Pa., are now under construction. The new buildings, which will be fireproof and of reinforced concrete and steel, will afford an additional floor space of about 6 acres and will be devoted chiefly to the manufacture of transformers with a capacity greater than 500 kv.a. The new group of buildings will consist of several one-story structures, the largest of which will contain about 157,000 sq. ft. of floor space. It will be of exceedingly heavy construction with crane lifts of about 55 ft. Cranes of 75-T. capacity will be installed. A four-story reinforced concrete and steel building with a floor space estimated at 135,000 sq. ft. is also included in the additions.

At present the works covers approximately 7 acres of land and is devoted entirely to the manufacture of transformers with a capacity of 500 kv.a. and less. The new additions will now allow the company to carry out its long contemplated expansion in the transformer field and will form a selfcontained unit for the manufacture of transformers of all sizes.

With the exception of the steel framework which is being erected by the American Bridge Co., Stone & Webster, Inc., has charge of the building according to the plans and specifications and under the general supervision of Bernard H. Prack, architect and engineer. The new buildings will be ready for occupancy about Nov. 1.

Under the new management, the Alberger works at Newburgh will be used for building pumps and other auxiliary apparatus while the Carteret works will manufacture the large condenser equipment.

Fynn-Weichsel Motors to Be Installed in Toledo Factory

AN UNUSUALLY interesting motor installation is to be made in the new plant of the Herbron Mfg. Co. of Toledo, Ohio, by the Wagner Electric Corp.

The Herbron Mfg. Co. will engage in the manufacture of drop forgings. Power will be supplied by 20 Wagner motors. Ten of these will be of the squirrel cage type, and the other 10, of equal horsepower, will be Fynn-Weichsel motors which will compensate for the low power-factor of the squirrel cage motors giving the entire installation unity power-factor over practically the entire load range. This is the first entirely new installation which has been worked out by the Wagner engineers using the Fynn-Weichsel motor and the results obtained in service will undoubtedly be closely watched by many engineers.

These motors start as slip ring induction motors, having starting torque characteristics much more favorable than the usual squirrel cage motor, that is, they will develop 150 per cent torque with a starting current of from 150 to 200 per cent. After the motor attains synchronous speed, which it will do easily with 150 per cent load, it becomes a self-excited synchronous induction motor.

Wilhelm Schmidt

DR. WILHELM SCHMIDT, whose pioneer work relating to the art of steam superheating led to the development and wide use of locomotive superheaters, died Feb. 16 at Bethel near Bielefeldt, Germany, at the age of sixty-six.

Dr. Schmidt's life is remarkable when viewed by the limitations which in European countries, as a rule, are placed upon individuals by traditions of class and education. Dr. Schmidt was the son of a villager and started his career as a locksmith. It was entirely through coincidence that his great natural ability to reason correctly on matters of physics and engineering came to the attention of prominent men who made it possible for him to educate himself and carry through the realization of his ideas. In early years

he recognized the great importance of superheating in the economy of steam engines and spent the larger part of his life in advocating this practice and in building up an organization which was able to carry his ideas to commercial success. His best known accomplishment was the creation of a practical locomotive superheater but he also did much in practical superheating for steamships and stationary power plants.

During the last 10 yr. of his life, he spent much effort and money in demonstrating practical means to combine the thermal advantages of high superheat with the advantages of high steam pressures, which he termed "super pressures." While he did not live to see his inventions relating to steam super pressures widely used, he had the satisfaction of having the engineering fraternity of his own country acknowledge the genius of his conceptions in this field, also. Many unusual honors were conferred upon him, one of the universities of his country even giving him an honorary degree of Doctor of Engineering, a remarkable tribute to a man entirely self-educated.

Plans for New Des Moines Plant Drawn Up

PRELIMINARY PLANS for the $16,000,000 Des Moines Electric Co. power station at Des Moines, Iowa, have been completed and submitted to Proudfoot, Bird and Rawson, architects who will design the exterior of the building.

Operations on the building of the first unit of this plant will be started within the next 30 or 60 days, it is announced. The first unit will contain two generating units and will cost approximately $6,000,000. Contracts for the generating apparatus have already been let to the General Electric Co. and to the Allis-Chalmers Co.

The ultimate plant will consist of five turbine units and will be completed over a number of years as the demand for power becomes necessary.

All of the engineering work for the station will be performed by the engineering department of the company at Chicago.

Thomas J. Lucas, chief engineer in charge of construction of the Illinois Power and Light Corporation, will have charge of the work.

News Notes

THE ALBERGER PUMP & Condenser Co., of New York, has recently been absorbed by the Wheeler Condenser & Engineering Co., of Carteret, N. J., thus combining the lines of two of the oldest manufacturers of condensers and auxiliaries.

There will be no change in the management of the Wheeler Condenser & Engineering Co. and it will continue under the direction of J. J. Brown as president. George Q. Palmer, formerly chairman of the Board of the Alberger Pump & Condenser Co., will serve as one of the directors of the Wheeler Condenser & Engineering Co. Mr. Palmer and several of his associates will take an active part in the business of the Wheeler Co. The combination of the Engineering Staffs and experience of the two companies as well as the larger facilities places the Wheeler Condenser & Engineering Co. in a position to render greater service to its customers.

MANCHESTER TRACTION, Light & Power Co., with headquarters at Manchester, N. H., is planning to improve its existing water power plants at Garvin's Falls on the Merrimack and Kelly's Falls on the Piscataquog Rivers by the installation of modern turbines and generators which will substantially increase the output of the two plants.

At Garvin's Falls the work will consist of the removal of the four existing horizontal units and the substitution of two vertical units together with a modification of the building, while at Kelly's Falls a vertical turbine will replace the single horizontal one now in use. Stone & Webster, Inc., Boston, Mass., has been engaged to design the changes and install the new units.

PLANS HAVE RECENTLY been completed by the Columbia Power Co. for the construction of a large new power station near Cincinnati, located on the Ohio River. Two 40,000-kw. turbine-generators have been ordered for the initial installation. The new plant will supply power for distribution to Cincinnati and adjacent territory. This power will be used for lighting street railway and industrial purposes. The units just ordered are two G. E. Co. 40,000-kw. tandem compound turbines, each connected to a generator rated 38,000 kw., 85 per cent power factor, 13,200 v., and a 2000-kw., 70 per cent power factor, 2300-v. service generator. The turbines are designed to operate at 550 lb. gage, 725 deg. F. total temperature and 1 in. absolute back pressure. Provision is made for reheating the steam and for steam extraction for feed water heating.

J. L. MOORE, PRESIDENT of the Moore Steam Turbine Corp., Wellsville, N. Y., died suddenly, April 2, after a slight illness of a few days. The end came as a severe shock because of the fact that Mr. Moore had been attending to business and had been in the best of spirits practically up to the time of his death. He is survived by a wife and daughter.

Mr. Moore came to Wellsville about 20 yr. ago in the capacity of general manager and chief engineer of the Kerr Steam Turbine Co. His splendid work placed that company in the front ranks of the small turbine industry. Between 7 and 8 yr. ago, he incorporated his own company and built his own plant. This company, from its inception, has made splendid progress and has been the source of gratification to its stockholders.

QUIGLEY FURNACE Specialties Co.'s Chicago office will be moved to larger quarters on May 1, at 9 So. Clinton St.

ARTHUR S. THOMAS has recently assumed his duties as manager of the New York office of McClave-Brooks Co. of Scranton, Pa.

F. KENNETH MORRISON, son of F. A. Morrison, secretary of the Mason Regulator Co., has been appointed as traveling representative in the sales department of that company.

H. A. SCHULTZ, formerly sales manager of the Frederick Pump Co., has been appointed manager of the newly opened office of the Moore Steam Turbine Corp., Wellsville, N. Y., at 319 Third Ave., Pittsburgh.

WILLIAM C. RUDD, formerly of Louisville, Ky., has opened an office in Cincinnati, where he is engaged as consulting engineer in the steam engineering field as applied to water, power and heating plants and industrial purposes.

G. A. SAWIN, assistant to manager, Supply Sales Department, Westinghouse Electric & Mfg. Co., has been elected chairman of a new section of the Electric Power Club. The section, including instruments and instrument transformers, was recently organized.

T. R. HARRISON has assumed charge of the Research Department of the Brown Instrument Co. of Philadelphia, Pa. Mr. Harrison was formerly associated with the Pyrometry Department of the Bureau of Standards and more recently with the Champion Porcelain Co. of Detroit.

C. E. REESE, formerly connected with the stoker sales and publicity departments of the Westinghouse Electric & Mfg. Co., has been appointed general manager of the Bluefield Gas & Power Co. at Bluefield, W. Va., by Walter Whetstone, president of the Southern Gas & Power Corp.

AT A RECENT MEETING of the Board of Directors of Johns-Manville, Inc., the following officials were elected: T. F. Manville, chairman of the Board; H. E. Manville, president; L. R. Hoff, vice-president and general manager; W. R. Seigle, vice-president and general manager of Factories and Mines; J. E. Meek, vice-president; J. W. Perry, vice-president; J. S. Carroll, vice-president; A. C. Hoyt, secretary and treasurer; T. F. Manville, Jr., assistant secretary and treasurer.

IDEAL COMMUTATOR Dresser Co. announces the removal of its organization from Chicago into its new factory at Sycamore, Ill. Sycamore is just on the outskirts of Chi-

cago and the new factory will provide improved facilities for manufacture.

SURVEYS FOR the power plant of the Pringle Falls Power & Water Co., on the Deschutes River in Oregon, have been completed, it was recently announced by Oswald West, president of the company. The company plans to develop 6750 theoretical horsepower for use in pumping water for irrigation from wells in the Fort Rock valley.

C. J. TAGLIABUE MFG. CO., Brooklyn, N. Y., has added to its instrument line, a combined recorder-controller. In this design an air-operated temperature controller mechanism and a recording thermometer are mounted in the same case and are actuated by the same thermostatic system. An important improvement is the entire elimination of the rubber connections usually employed in instruments of the combined form.

THE FIRST BIG STEP in the actual construction of the new $2,000,000 power plant of the Union Gas & Electric Co. to be erected near Cleves, Ohio, at the confluence of the Ohio and the Big Miami Rivers, was taken recently when the contract for laying the foundation of the plant buildings was awarded to the Foundation Co. of New York City.

Additional contracts on the construction of the new main power plant of the Union Gas & Electric Co., at Cleves will be awarded in the near future, officers of the company said recently.

Books and Catalogs

BLUEPRINT READING, by Joseph Brahdy; 108 pages, size 8 by 11 in., cloth; New York, 1923.

The ability to read blueprints is necessarily a prime requisite of any contractor, machinist, pattern maker, erector or, in fact, anyone who works from the design of others. It means the ability to interpret correctly the meaning of any working drawing, in isometric or in orthographic projection, so as to insure a correct reproduction of that which the designer had in mind.

Detailed instructions are given on this subject in this book. Topics discussed include representation of an object, visible and invisible parts of a working drawing, measurement and scales, orthographic projection, conventional practice and sample drawings machine parts. The book is bountifully illustrated, as a book of this nature must be, and the text is lucid and to the point.

MECHANICAL WORLD YEAR BOOK, 1924; 348 pages, size 4 by 6 in., cloth, Manchester, 1924.

In this the latest edition of this little hand book for mechanical engineers a new section has been added on the combustion of fuels. Notes and data are given on the composition and properties of air, the quantity required for combustion, weights and volumes of air and the products of combustion and the calorific value of various kinds of fuel, solid, liquid and gaseous. A new section has been added also on the strength of flat plates which embodies a summary of the various rules for finding the strength of rectangular, square and circular plates both supported and unsupported.

POWER PLANT LUBRICATION is the title of an interesting 60-page book issued by the Tide Water Oil Sales Corp. of New York. This is a treatise covering the latest developments in the lubrication of Power Plant machinery.

Beginning with an explanation of friction and its effects, the book takes up the general discussion of lubrication. This is followed by a chapter on lubricants and one on the testing of lubricants. Next in order, the lubrication of various types of machines is considered, including steam engines, turbines, Diesel engines, semi-Diesel engines, generators and motors and finally the lubrication of auxiliaries. The book is attractively illustrated with numerous diagrams in two colors showing the application of lubricants to power plant equipment.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.

required by the Act of Congress of August 24, 1912, of Power Plant Engineering, published semi-monthly, at Chicago, Ill., for April 1, 1924.

State of Illinos,
County of Cook,
ss.

Before me, a Notary in and for the state and county aforesaid, personally appeared Charles S. Clarke, who, having been duly sworn according to law, deposes and says that he is the Secretary of the Power Plant Engineering, and that the following is to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of Aug. 24, 1912, embodied in section 443, Postal Laws and Regulations, printed on the reverse of this form, to-wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:
Publisher, Technical Publishing Co., Chicago, Ill.
Editor, Arthur L. Rice, Chicago, Ill.
Managing Editor, none.
Business Manager, E. R. Shaw, Chicago, Ill.

2. That the owners are: (If the publication is owned by an individual his name and address, or if owned by more than one individual the name and address of each, should be given below; if the publication is owned by a corporation the name of the corporation and the names and addresses of the stockholders owning or holding one per cent or more of the total amount of stock should be given.)
Technical Publishing Co., Chicago, Ill.
E. R. Shaw, Chicago, Ill.
A. L. Rice, Chicago, Ill.
K. L. Rice, Chicago, Ill.
Charles S. Clarke, Chicago, Ill.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)
There are none.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed through the mails or otherwise, to paid subscribers during the six months preceding the date shown above is ..... (This information is required from daily publications only.)

Chas. Sanford Clarke, Secretary.

Sworn to and subscribed before me this 22nd day of March, 1924.
E. C. Van Arsdel.
(My commission expires February 16, 1928.)

NOTE.—This statement must be made in duplicate and both copies delivered by the publisher to the postmaster, who shall send one copy to the Third Assistant Postmaster General (Division of Classification), Washington, D. C., and retain the other in the files of the postoffice. The publisher must publish a copy of this statement in the second issue printed next after its filing.